THE
PEOPLE'S
BOOKS

ZOOLOGY

ZOOLOGY

THE STUDY OF ANIMAL LIFE

By E. W. MacBRIDE, F.R.S.

LONDON: T. C. & E. C. JACK
67 LONG ACRE, W.C., AND EDINBURGH
NEW YORK: DODGE PUBLISHING CO.

CONTENTS

CHAPTER I

CHAPTER II

CHAPTER III

CHAPTER IV

CHAPTER V

CHAPTER VI

CHAPTER VII

CHAPTER VIII

ZOOLOGY

CHAPTER I

THE SCOPE OF ZOOLOGY.

THE word zoology is derived from the Greek word *zōon*, which meant "animal," and from the termination *-logia*, which signified a discourse. The name therefore, as might be expected, denotes the **science** of **animals**, and is therefore narrower in its scope than the science of **biology**, which deals with everything living and of which the science of zoology forms a subdivision.

We see, therefore, that at the outset we are faced with two fundamental questions, viz. (1) What is **life**? and (2) What is an **animal**? To no two questions is it more difficult to give a precise answer than to these. If with Herbert Spencer we define life "as the continuous adjustment of internal to external relations," who is the wiser, or who has any better conception of life as a result of the definition?

The better way of approaching the problem is the historical one, and instead of asking "What is life?" or "What is an animal?" let us rather ask how the ideas embodied in the terms "life" and "animal" took their origin.

The word "animal" is derived from the same root as the Latin word "anima." This originally denoted simply "wind" or "breeze." It was then used to denote "breath," *i.e.* the air sucked into and ejected from the lungs in respiration. Breath was recognised by the ancients as the universal concomitant of life and activity in man and animals, and indeed it was regarded by them as the essential principle or *cause* of animal life. So the word animal signified in the first instance "a breathing being," but the significance of the word was soon extended so as to include all beings which actively moved, such as insects, even if they did not obviously breathe air. The wider idea of life was connected by the ancients with the idea of **growth**, and the proper name for the science of life would be **Physiology**, a word compounded of the termination *-logia* and the word *phusis*, which signified growth in the widest sense. The good old word physiology had however been used for so long in connection with medicine to denote the science of the life of man that Huxley thought it necessary to coin a new word, **Biology**, to denote life in its widest sense. The etymology of the term is bad Greek, for *bios* never denoted "life" in the general sense in that language. However, all confusion of thought was avoided by the new term, and we must forgive its faulty derivation. As the idea of animal is that of a moving being, so the idea of life is that of something that grows. These ideas were taken over from primitive times by that orderly careful type of thinking characteristic of our own day, and denominated **science**; by it they have been recast, because not everything that moves is an animal—for instance, a volcanic bomb or a shooting star is not included in the term—nor is everything that grows living—for instance, a snowball rolling down a snowy hill or a crystal suspended in its mother liquor both grow, but neither is regarded as alive.

Life is defined for science as the state or condition of a being which grows and which reproduces itself. The growth postulated is however very different from that of the snowball or of the crystal. In these two cases increase in size results from the addition of new matter, which is laid on in successive layers round the original matter which persists as the core. But in the case of a being which has life—or, as we term it, a **living being** or **organism**—growth results from the intercalation of new material between the interstices of the finest particles of the old: this is termed growth by **intussusception.** In this way the child grows to manhood; so that to take the face, for instance, although the absolute size of the features is more than doubled, their general proportions relative to one another remain the same. By **reproduction** is meant the formation of new living beings by the cutting off of small portions, termed **germs**, from pre-existing living beings, which then by growth come to resemble the beings from which they took their origin. Only in this way are new living beings formed; new life can only arise in connection with pre-existing life, and reproduction is only a special case of growth. It is a marvellous thought to reflect that although living beings are continually dying, *i.e.* being turned into dead matter which neither moves nor grows, yet dead matter can only be converted into a living matter—into a part, that is, of a living being—through being eaten or assimilated by that being.

An **animal** is defined, for the purposes of science, as a living being which moves and which requires for its sustenance food containing peculiarly complicated chemical compounds known as **proteids**; these in the majority of cases are taken in the *solid* form and **digested,** *i.e.* melted inside the animal's body. **Plants**, on the other hand, are defined as living beings which can only take their food in the form of liquids and gases, but which require only simple chemical compounds for their sustenance, and which do not move except so far as movement is involved in the process of growth. But in practice these definitions are not rigidly adhered to. The reason for this is that both plants and animals can be divided into groups, the members of which exhibit the closest resemblance to one another, and a particular living being is reckoned as animal or plant according to the general characteristics of the group to which it belongs, even should its own individual peculiarities be in some respects irreconcilable with the general definitions of animal or plant. Thus the sensitive plant droops its leaves and shuts up its leaflets when touched, just as the snail draws in its tentacles and retires into its shell when it is irritated; and yet the sensitive plant is reckoned a plant, because in all its characters it closely agrees with the plants of the Pea order. The carnivorous plants form hollow cups at the tips of their leaves, which entrap insects by means of slanting hairs and other contrivances. These insects die and their bodies are digested, and the resultant materials are absorbed by the surrounding tissues of the plant which act like the walls of the stomach of an animal. Nevertheless we reckon these carnivorous plants as plants, because in all the details of their structure—wood, leaves, flowers, &c.—they closely resemble ordinary plants. Similarly there are some minute living beings which are green and which can live on quite simple chemical compounds like plants, but which are nevertheless reckoned as animals because of their likeness to other living things which are undoubtedly animals. It must be admitted, however, that there is a great deal more doubt about the true position of these "plant-animals" than there is about the position of the "animal-plants" referred to above—a doubt which is emphasized by the fact that the same group of beings is lectured on by professors of both botany and zoology, and described in text-books which deal with both sciences. In many cases where animals of some size have a green colour and are apparently able to subsist on simple chemical substances, this appearance has been shown to be due to the fact that their bodies are the home of multitudes of minute plants, which grow in them and give them their colour by shining through the more or less transparent substance of the body, but which sooner or later are digested by the animals in which they live and serve as their food.. The only plant-animals which are left un-accounted for are extremely minute microscopic forms, in the case of many of which, the question of whether they shall be ranked as plants or animals can only be decided by a careful balance of the evidence for and against.

For all practical purposes the definition of an animal as a living thing—or, to use the shorter and more convenient term, an **organism** which can move and take in solid food which must contain proteid—is a good definition, and certainly expresses the *idea* which rises in the mind of a scientific man when he names the word animal.

CHAPTER II

THE PRACTICAL IMPORTANCE OF ZOOLOGY.

HAVING in the previous chapter given the reader some idea of what the science of zoology is about, we propose in the present one to attempt to give him some conception of the enormous practical importance of the subject. We use the word *practical* in its widest sense: not only in the sense of importance in helping man to make his living, but of importance in aiding man to understand his relationship to this wonderful universe in which he finds himself. Indeed it may be said that a rational conception of his relationship to the universe is just what distinguishes the civilised man from the savage. Since he was able to think at all, man has formed conceptions of his relations to the universe which may be termed working hypotheses. These still survive amongst large sections of mankind, and even amongst many who consider themselves civilised, as beliefs in **magic** and other superstitions, but they are not based on data which have been thoroughly examined and tested. It is the great characteristic of science that it will not accept any data except those which have been subjected to the most searching examination, and experience has shown that by the way of science alone, and not by the ways of magic and ancient religion, is it possible to gain any mastery over Nature.

Now the first reason why zoology is such an eminently practical science is that we are ourselves animals. Our bodies are made of fundamentally the same stuffs as their bodies and are subject to the same laws. Whether the **animus** or spirit in us, which knows and feels, differs in kind or only in degree from the **animus** in them, is a question which, strictly speaking, lies outside the province of zoology altogether. The science which should attempt to deal with questions like these is termed Comparative Psychology. In virtue of possessing the power of **speaking**—a power possessed by no other animal—man is able to explore and make the acquaintance of the **animus** which resides in each of his fellow-men; but this avenue into the inner consciousness of animals is closed, and no other exists which can lead the inquirer very far. Zoology, then, concerns itself with what can be directly observed about animals, viz. the structure of their bodies and their behaviour, without trying to pry very much into what they know and feel.

But the study of the structure of the bodies and of the behaviour of animals throws an enormous amount of light on the working of the parts of the human body. The only other way of finding out the uses of the parts of the human body is to observe what happens when one part is thrown out of gear, but this method is subject to serious limitations. When one part is diseased, as St. Paul has said, all the other parts suffer with it, *i.e.* do not act normally, and it is sometimes difficult to separate the effects due to the absence of the working of a particular part from the effects due to the abnormal working of the other parts. But in the various groups of animals which are most nearly allied to man we have bodies made up of the same parts as our own bodies; but these parts are of different relative sizes, and we find that when one part is greatly enlarged a particular kind of behaviour is exaggerated, and that when it is relatively much diminished certain elements of behaviour tend to disappear; and we can reason with complete confidence from the exaggerated structure to the corresponding behaviour, and yet we are dealing with organisms in which all the parts are working harmoniously together. To give a very simple instance: there is a band of fibres connecting our two eyes beneath the brain which is called the **optic chiasma.** It is believed that the function of this is to focus the two eyes on a single object so that it can be seen distinctly. This belief is borne out by two facts: first, in ordinary fish which have more or less blade-like bodies the optic chiasma is absent: this is what is to be expected if our view as to the function of the chiasma is correct, for such animals could by no possibility focus the eyes which are on opposite sides of their bodies on the same object; secondly, in insectivorous birds the optic chiasma is extremely large, and this again is what is to be expected, for such birds which pursue their minute prey on the wing have need of extremely accurate focussing, and owing to the speed at which they travel must rapidly alter their focus as they approach their prey. For the education of any man who wishes to deal in an intelligent and progressive manner, and not merely in a traditional manner with the ailments of the human body a preliminary training in zoology would appear to be absolutely necessary.

But the study of zoology is of enormous importance on many other grounds. A large part of our food is furnished by the bodies of animals. Proteids, which form a necessary part of our sustenance, can be obtained most directly from this source. A few semi-civilised races are exclusively planteaters, but the leading dominating races of mankind who are in the van of the march of culture have always been flesh-eaters. Primitive man also was a hunter and a flesh-eater, and civilised man in moments of relaxation throws off the shackles of civilisation and becomes a hunter again. Now the scientific breeding and care of cattle is a branch of applied zoology, and one that is growing in importance. So long as one was concerned merely with the raising of cattle in old civilised countries like our own, in which through centuries of trial and error traditional rules had been hammered out, the agriculturist got on fairly well without zoology, but when cattle-breeding was begun in new countries where conditions are widely different from home conditions, then the necessity of a knowledge of zoological science became clamant. Frozen meat imported into the London docks was found to be marked by circular scars, caused by the presence of a worm which lay coiled up therein, and the question arose, was such meat dangerous for human consumption or not? Only the zoologist could answer this question, and the answer he gave was that the eggs of this worm pass through a necessary part of their development in the body of a fly which is not found in Great Britain, and hence that the meat infested by these worms could be consumed with impunity. Again, the sea furnishes us with a large part of our animal food. In 1897 it was reckoned that the produce of the Canadian fisheries, imperfectly exploited though these were, exceeded in value the famous Manitoba wheat-harvest. The question, whether we are exhausting our fisheries or not, has been raised again and again. When the steam trawler with its improved fishing gear was introduced, a cry arose from the longshore fishermen that their new rivals were ruining fisheries by destroying the spawn. The zoologist was the only person who could settle this dispute, and he did so by showing that the spawn of most of the valuable fishes floated and was quite out of the reach of the trawls of the new fishing-boats. In the future we confidently anticipate that zoology will be more and more applied to the scientific exploitation of the "harvest of the sea."

But in our opinion the greatest value of zoology is to be found in another aspect of its teaching. As we study the lives of animals more closely we become impressed with the tremendous competition which goes on between different kinds of animals. If all the young born in any one species were to survive and grow up, that species would in a very few years overrun the entire surface of the globe. In the case of pheasants it has been calculated that if all the eggs which a pheasant laid were to be hatched and all the young chicks were to survive to maturity and lay the normal number of eggs in turn, a period of eighteen years would suffice to produce from the offspring of a single pair a crowd of pheasants which, if placed side by side touching each other, would cover the entire surface of the globe including the sea, and even then a large number would be left over. But there are many species of animals far more prolific than the pheasant; the cod, for instance, lays nine million eggs in one season, and the only thing which prevents all the food material in the sea being made into young cod in the course of a year or two is the enormous destruction which the young cod are subject to at the hands of their innumerable enemies.

We may make the matter a little clearer to ourselves if we compare the earth to a huge prairie of dry grass and compare each species of animal to a fire which has been lighted in it. Each fire tends to spread outwards so as to overrun the whole prairie, but each is limited in the possibilities of its spread by the spread of its neighbours. One may notice on the banks of the Clyde an oyster-catcher busily gaining its living. This is a bird which feeds largely on the shellfish which are exposed at low tide. The question rises in one's mind, why are not all the rocks denuded of their molluscan inhabitants by this bird? The only answer is that the nestlings of the oyster-catcher are in turn destroyed by some enemy, and that oyster-catchers are thus prevented from becoming inconveniently numerous. It sometimes occurs that a species of animal reaches a new country where its enemies are too feeble to seriously thin its numbers. Then an enormous multiplication occurs, and the species spreads in such a manner as to threaten to crush out all other forms of life. If it finally succeeded in doing this it would no doubt bring its own existence to an abrupt termination, for it would exhaust its own food supply. The English rabbit transported to Australia increased at such a rate as to make pasturage well-nigh impossible, so that an enormous sum of money has now to be spent annually in order to keep it in check.

Now these facts have a double interest for us. First, civilised man for his own use insists on rearing enormous herds of a few kinds of domesticated animals and enormous crops of a few species of cultivated plants. Such thickly massed crowds of individuals belonging to a single species are rare in Nature, and are as stubble to the flame if once invaded by a successful enemy. If an enemy like the boll-weevil gains an entrance to his cotton-fields, how shall man protect himself against it? The answer which one of the best living entomologists gives to this question is as follows: "The only way in which a problem of this kind can be attacked is by a careful study of the habits and life-history of the insect enemy; such a study will be sure to reveal some weak point in the armour of the foe, and it is there that we must attack him." A knowledge of zoology is essential, therefore, for the proper protection of our crops and herds, and indeed how could it be otherwise? Are not we ourselves a species of animals maintaining our right to existence by a hard struggle against our competitors? And it may be added that these competitors are just as ready to attack our own bodies as they are to devour our domesticated animals and plants. Some of them, which have accustomed themselves to live in our blood, run riot there and bring pain and death in their train. Only by a careful study of their life-history is it possible for us to guard ourselves against them. By means of such studies the American biologists have made the Isthmus of Panama, once a graveyard for Europeans, one of the healthiest districts in America.

The second interest which the competition between species has for the thoughtful man is its bearing on the history of the human race itself. There is no doubt that for tens of thousands of years the numbers of mankind were kept down by internal and external enemies, just as are the numbers of the oyster-catcher. But in the last two thousand years, and more notably in the last two hundred, and most notably of all in the last fifty, man has been learning to know and conquer his enemies. The result of this has been that population amongst civilised nations has begun to increase at an alarming rate, and all sorts of problems have sprung up in consequence. The nature of these problems is clear, and their occurrence seems inevitable to the man who has had a zoological training, but it is far from clear to many of our so-called thinkers who have not had this advantage, otherwise we should not hear proposals put forward by Fabian societies and similar organisations that the State should undertake the care and nurture of the babies of the poor, thus relieving the least competent members of the State of the last deterrent to reckless reproduction. If we are going to try to prevent Nature's method of choosing the best, viz. the elimination of the poorest and weakest, we must surely substitute for it our own selection, else we shall suffer the fate which befalls half-hearted meddlers in great affairs.

CHAPTER III

THE LIVING SUBSTANCE.

Having gained some conception of the nature and bearing of zoological science, we may now proceed to examine some of the special problems with which it deals. In a book of such limited size as the present volume it would be futile to attempt to cover the whole extent of the science: the most that can be done is to try to select a few samples of the kind of question that zoologists have tried to solve.

All life expresses itself in movement, either, as in the case of plants, in the movement due to growth or, as in the case of animals, in the movement of fully grown parts, which return after their movement to their former condition Now if we leave aside for the present the movement due to growth and confine our attention solely to the characteristic animal movement of adult parts, the first question which confronts us is this: How is this movement produced? If we examine small fragments or very thin slices of the part of the body which is the seat of movement, we shall always find clear **fibres**, which when movement occurs grow *shorter* and *thicker*. These fibres, which are termed **muscle fibres**, are the direct cause of movement in all the higher animals. In the lower animals we find irregular masses of clear substance which throw out tongues in a peculiar way and flow first in one direction and then in another. The simplest of all animals, the proteus animalcule *Amœba*, consists entirely of a small lump of this substance, which moves by flowing out in tongues in the way described. These movements are consequently termed **amœboid**, but they are however of fundamentally the same character as the contraction of muscle fibres, since the flowing is due to the contraction of one part squeezing out the rest. We often find also, both in simple and complex animals, projecting hair-like structures termed **cilia** or **flagella**, which vibrate rhythmically and propel the whole animal along if it is small, and propel the surrounding fluid in a current past the animal if the latter is larger. But the vibration of these cilia and flagella has also been shown to be due to the alternate contraction of narrow slips on each side of the vibrating structure; so that we may sum up the matter thus: *all animal movement is due to contraction in some portion of the moving parts whereby that portion becomes shorter and thicker.*

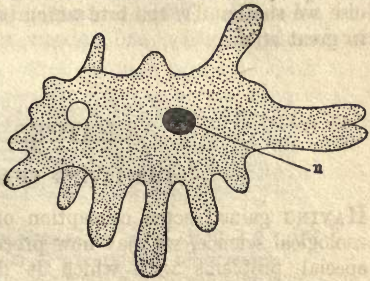

FIG. 1.—An *Amœba* progressing. The direction of movement is towards the right; *n*, the nucleus.

If we could thoroughly explain how this contraction is brought about, we should have penetrated much more deeply into the mystery of life than it has so far been possible to do. But although a complete explanation is not yet forthcoming, certain broad facts in connection with moving parts may be emphasized The clear substance which is the seat of contraction is always surrounded by a skin consisting of a thin elastic membrane. When we have to deal with amoeboid movement, this skin is so thin and delicate that it is constantly being burst and then formed again round the clear substance which has been extruded through the break. This substance seems to be of a *fluid*, or at least a *semi-fluid character*, and the act of contraction seems to be accompanied by an increase in *volume* in this substance, for the fibre in shortening its length increases, as we have seen, its diameter and gains in volume on the whole—a fact familiar to every schoolboy who "raises" his biceps muscle. In the most highly developed contracting fibres, such as are found in the flesh of our own bodies and that of the highest animals, we meet with a phenomenon known as the **cross-striping** of the fibre. Every contractile fibre when at rest is found to be crossed by a series of dark plates, placed at regular intervals from one another like the sleepers on a railway line. Between these plates the fibre is made up of clear semi-fluid substance. When contraction occurs the clear substance increases in quantity, and appears to be imbibed by the dark

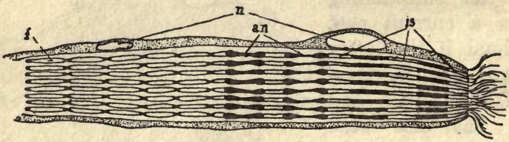

FIG. 2.—Part of a cross-striped muscle fibre: *an*, anisotropic substance ; *is*, isotropic substance in a single fibril ; *f*, a fibril ; *n*, nuclei.

plates which swell and at the same time become less dark in colour. The dark plates are known by their behaviour towards light to be *solid*, and their purpose seems to be by exercising an attraction on the fluid substance to increase the rapidity of the contraction. It is known that cross-striped fibres contract much more rapidly than plain ones, and the striping is best marked in the fibres which move the wings of insects ; and these muscles must in many cases contract and relax many hundreds of times in a second.

The increase in volume then of the semi-fluid substances seems to be a proximate cause, if not *the* proximate cause, in producing contraction. Now the only way in which we can conceive of this increase in volume being brought about is by chemical decomposition. When a match is applied to gunpowder contained in a gun-barrel an enormous increase in volume takes place, owing to the fact that the materials of the gunpowder *oxidise, i.e.* unite with the oxygen of the air so as to produce great quantities of highly elastic gas. Now we find that if we remove all oxygen from the neighbourhood of the contracting parts of an animal, they very soon cease to be capable of contraction. They are paralysed; and it seems a plausible suggestion that the chemical decomposition connected with contraction is of the nature of an *oxidation.*

Besides its manifestation in the form of movement, life gives evidence of its presence in **secretion.** By secretion is meant the continuous production of substances, not themselves living, which subserve some secondary use for the animal. Thus the hairs which clothe our bodies are composed of dead dry horny substance, but they are of inestimable value in protecting our bodies against undue loss of heat. But secretions may be fluid: the digestive juice which reduces our solid food to the liquid form, and thus renders it capable of mingling with our living substance and contributing to its "growth by intus-susception," is such a secretion. The point which we wish to emphasize at this juncture is that *whenever we penetrate to the point where secretion is being actively carried on we find masses of clear semi-fluid substance essentially similar to that which we found in contractile fibres, and that it is by the continual decomposition of this substance that the secretion is produced.* Similarly, if we investigate any quickly growing part we find the same clear semi-fluid substance—in a word, all manifestations of life are associated with this substance, or, putting it differently, this substance is *the* living substance, and the body of an animal consists essentially of this substance and of its secretions.

This marvellous "living substance" is termed **protoplasm,** and since in it is hidden the secret of life we may look at it a little more closely. It is not a simple uniform substance, but a mixture of substances. In every mass of living protoplasm we may detect a **nucleus** or several nuclei. The nucleus is usually a rather compact body of an oval or spherical shape, but in exceptional cases it may take the form of a rod, or even of a spiral thread—or it may be represented by a cloud of granules. In the vast majority of cases, however, it is an oval or spherical body. Its distinguishing feature is that it contains a substance called **chromatin,** which has a remarkable power of absorbing staining fluids such as carmine, hæmatoxylin (which is an extract of logwood), &c. Now in very small animals it sometimes happens that there is only one nucleus present; it is then possible to cut the body of such an animal into two parts, one of which includes the nucleus and the other does not. The part devoid of a nucleus can live for some time and carry out movements, but it is unable to digest or assimilate food, and in a short time it dies. We conclude, therefore, that the production of the substances which melt solid food (*i.e.* **digestion**), and the building up of the digested food into new living material (*i.e.* **assimilation**), are functions which can be carried out only by the aid of the chromatin. If we apply the term protoplasm to the living substance taken as a whole, and call the body in which the chromatin is stored the **nucleus**, then the rest of the living substance is termed **cytoplasm.** Broadly speaking, the amount of nuclear material present bears a more or less fixed proportion to the amount of cytoplasm surrounding it, and it may take the form of a single-branched nucleus or of a number of smaller rounded nuclei. Now there are some animals so small that a single nucleus suffices for all their needs; but in most animals there are many nuclei, and in all the higher groups of animals (termed collectively the **Metazoa**) there is an area of cytoplasm surrounding each nucleus which is marked off from the rest of the cytoplasm by a thin membrane. Such an area is termed a **cell**, and when the living substance of an animal is thus divided up it is said to possess **cellular structure.** The cells may be compared to the bricks in the wall of a house. Animals devoid of cellular structure are termed **Protozoa** (*lit.* first-animals). Most of these are of microscopic size, and very many have only one nucleus. Such animals have been compared to a single cell of the body of a higher animal and have been termed **unicellular,** but the comparison is misleading. They are closely allied to other Protozoa of slightly larger size and which possess numerous nuclei, and it is quite wrong to compare the tiny sun-animalcule of our ditches with its two hundred nuclei to a single cell of a higher animal. The proper term to apply to Protozoa is **non-cellular.** A most distinguished American biologist has recently shown what the meaning of the cellular structure is.

We have seen that life amongst animals manifests itself in various ways, viz. by movement and by different kinds of secretion. Now each of these different ways implies that a different kind of chemical decomposition is going on in the cell, and the membranes separating the cells from one another derive their importance from the fact that they regulate the passage of materials in and out of the cells. Each cell is in fact a chemical factory, and the possession of cellular structure by an animal is really a sign of the number and variety of chemical processes going on in it. We have so far alluded chiefly to the decomposition or breaking down of complex chemical substance, which occurs in the cell whether the result of this be movement or secretion; but, as we have already hinted, a concurrent process of building up new living substance out of the food is also going on, else life would soon come to an end. This building up, which as we have seen is effected by the aid of the chromatin, is termed **anabolism,** whilst the decomposition is termed **catabolism,** and **metabolism** is used to denote the sum total of all the chemical processes occurring in the cell.

Neither anabolism nor catabolism can take place in the absence of oxygen, which must be constantly supplied to the living substance, as it is constantly being used up in the process of oxidation, which constitutes the principal item in the process of decomposition and is also an element in the processes of anabolism. The absorption of this necessary oxygen by the living substance is termed **respiration.** To sum up, we shall form the justest conception of the activities of living substance, if we regard it as in a continual state of *burning. Life is a fire*, as Buddha said long ago, and the scriptural story of the bush which burned and was not consumed exactly expresses the modern conception of the nature of life.

If we have once grasped this conception, certain conclusions will at once suggest themselves. The ordinary coal-fire burning in our grates would soon be extinguished if the ashes which result from the oxidation of the coal were not constantly removed. So it is with life: the products of decomposition, when they are so far broken down that they cannot be used again to build up new protoplasm by the addition of materials from the food, must be removed, or else they will soon put a stop to life. Such products are termed **excreta**, and the process of getting rid of them is known as **excretion.** The commonest substance which is excreted is the gas known familiarly but incorrectly as **carbonic acid.** This gas is very soluble in water, and as all living substance is bathed in water or some other fluid (*i.e.* blood) largely composed of water, it can be seen that ever opportunity is given for the removal of this compound. Lastly, when an animal takes in solid food and proceeds to digest it, there often remains a residue which resists the digestive juice. This residue is termed **fæces,** and the process of getting rid of it is called **defæcation.**

Since oxygen can only be taken into the living substances and the poisonous excreta got rid of by the process of diffusion, it follows that living substance can never be accumulated in large masses, but can only exist in the form of small granules, or of thin plates presenting relatively large surfaces to a circumambient fluid of some kind. By diffusion we mean the process by which two liquids or two gases become commingled, in consequence of the motion of the molecules of which they are made up. In the case of liquids this is always a slow process; and a solid mass of protoplasm a quarter of an inch in diameter, if such a thing existed, could no more be living throughout its whole extent than a block of coal could be burning throughout its whole extent. In both cases combustion could only exist at the surface of the respective masses.

The task of finding out the physical and chemical structure of living substance is one which ought properly to form part of zoology, but one which, on account of its difficulty and the amount of concentrated effort which it requires, has caused the growth of a subsidiary science devoted to its solution alone. This science is termed **Biochemistry.** We may briefly indicate some of the points which the devotees of this young science have already gained in their struggle with the mystery of mysteries. Since life is a fire, and since this fire requires the constant diffusion of oxygen into the living substance and of carbonic acid out of it, living substance must be a fluid, since only in fluids and gases can diffusion exist. All living substance contains large quantities of water and all life is suspended by drought, hence it is almost certain that the living substance is a thick solution of certain substances in water. It has been found that when solutions of complicated chemical substances, of such substances as gelatine for instance, are made, the solution may be perfectly transparent and yet refuse to pass through filter paper. This is attributed by biochemists to the circumstance that the molecules of such substances are arranged in groups which are of enormous size compared to the molecules of such simple substances as common salt, &c. They suppose that these complicated molecules are in fact bigger than the pores in the paper. When the molecules reach an extreme size, the solution ceases to be absolutely transparent and appears slightly cloudy, and such a mixture—we can hardly call it a solution—is termed an *emulsion*. Living substance is then supposed to be such a thick solution, or in some cases an emulsion. But what kind of substances form the stuff which is dissolved or suspended in the water? To such a question no perfectly satisfactory answer can be given, for when we begin to analyse living substance chemically, we kill it—and then our results give us the composition of dead and not of living material.

But we may perhaps assume that when living substance is killed by gentle heating its composition is not very much changed. It then forms what is called **proteid,** which, as we have learned, forms a necessary constituent in the food of all animals. By treatment with solutions of salt and by boiling with dilute acids, proteid can be split up into still simpler substances, and by a continuance of this treatment on the products of its decomposition we at last reach comparatively simple compounds whose chemical structure can be recognised. These compounds contain carbon, hydrogen, nitrogen and oxygen, and are of the class called **amino-acids.** The great characteristic of an **acid** is that it can combine with another kind of chemical compound called a **base** to form a neutral compound termed a **salt.** The acid has as it were a *hand*, by which it can grasp the hand of another compound. An amino-acid is an acid which is also at the same time a base—in a word, it has two hands, viz. an acid hand by which it can grasp a base, and a basic hand by which it can grasp an acid. The base to which it unites itself may be the basic portion of another amino-acid, and the acid which it grasps by the basic hand may be the acid portion of still another amino-acid. We see that in this way amino-acids can be linked together in long chains, and when proteid is broken up by boiling it with acid, what happens is that the links in these chains become separated from one another. Now an acid can be di- or even tri-basic—that is to say, that it may have two or even three acid hands instead of one, and so we see that there are possibilities of infinite complication in the structure of these compound amino-acids. But we know that proteid contains sulphur as well as the four elements named above; there must be therefore a sulphur-containing group attached somewhere in the amino-acid chain, and chromatin is known to be a compound of proteid with nucleic acid, which itself is a compound of phosphoric acid. We need not pursue the subject further; enough has been said to show that if the living substance be not widely different in structure from dead proteid, and if proteid be composed of enormously long amino-acid chains, then, even if every different kind of animal and plant has a different kind of living substance, there is enough possibility of variation in the amino-acid chain to account for them all. So far, this is by far the most plausible theory of the composition of living substance which has yet been put forward; but the working out of this theory in detail will consume many decades of experiments, and it is on this work in detail that its final verification depends. The best and final proof of its truth would be the building up of proteid out of simple substances in the laboratory. Some steps in this direction have been taken, but at every step it is as if one were following a road which continually forked and there were no sign-post to guide one as to which fork one should follow.

CHAPTER IV

THE VARIOUS KINDS OF CELLS: THE TISSUES.

We have seen that the living substance in the bodies of the larger animals is divided into cells. Now these cells are never all alike, but differ from one another in size, shape, and function. Nevertheless all these various sizes and shapes can be classified under a few leading forms, and a knowledge of these forms is a necessary prerequisite for the understanding of the language in which the bodies of the various kinds of animals are described. Indeed these forms may be compared to the alphabet of a language in which the various kinds of animals are sentences of different kinds. It is the necessity of learning alphabets of this kind which makes the study of zoology and of other sciences appear so dull and technical to the beginner. Once the alphabet has been thoroughly assimilated, zoology becomes intensely interesting. The schoolboy struggling with his declensions and his vocabulary

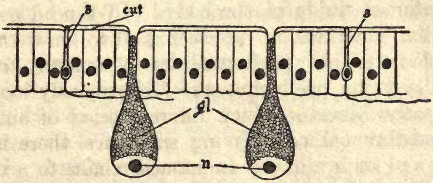

FIG. 3.—Diagrammatic representation of simple columnar epithelium containing gland cells and sense cells; *cut*, cuticle; *gl*, gland cell; *n*, nuclei; *s*, sense cell.

finds learning Latin dull work, but the finished classical scholar finds the reading of the ancient authors stimulating, elevating, and fascinating.

The simplest kind of cell is a columnar one with outer and inner terminal faces, and with a varying number of sides which fit against the sides of similar cells, so that the whole together constitutes a *pavement*, or as it is termed in zoology an **epithelium** (Gr. *epi*, upon; *thelion*, a tile). Such "pavements" form the external covering of the body in very many animals; they also line the stomachs and intestines of all animals which possess them. The individual cells are termed **epithelial cells**, and their height varies very much in relation to their diameter. The height may be so small that the cell appears like a flat tile, or it may be so great that the cell is a pillar. Where the matter has been most closely investigated it is found that each cell is united to its neighbours by little bars or bridges of living substance traversing the cell membrane. When we are dealing with an external epithelium, the normal state of affairs is that each cell secretes on its external face a horny or gelatinous membrane termed the **cuticle,** which protects the living material from the assaults of external enemies, whilst by its internal face it absorbs nourishment from the fluids of the body. In the case of an internal epithelium matters are rather different. The internal face gives rise to a secretion which helps to digest the food which has been swallowed, and through this same face the products of digestion are absorbed, whilst through the basal face of the cell these same products are given off into the internal fluids of the body. In the highest animals, however, the functions of producing the digestive juice and of absorption are not performed by the same cells. Some are specialised for producing the digestive secretions, whilst others merely absorb. Such secretion-producing cells are called **glandular cells:** they are generally arranged together in groups, and such a group is termed a **gland.** It generally happens that the cells forming a gland are arranged so as to surround a blind pocket-like outgrowth of the stomach or intestine. This pocket-like outgrowth may become branched, and a huge glandular mass may be the result of repeated branching. The human liver, which is the largest organ in the body, is an extreme instance of a large **branched gland.**

In the case of many land animals, where the outer surface of the body has to be constantly lubricated in order to prevent its drying up, the outer epithelium develops specially glandular cells which sometimes are arranged so as to line glandular pockets. The glands which produce sweat or **perspiration** in ourselves are examples of this modification. But it must be remembered that the thin membrane which these epithelial cells can produce on their outer surfaces is a secretion resulting from the decomposition of the living substance, and that no line can be drawn between such a secretion and a fluid one like our own perspiration for example, because every intermediate grade of secretion is known. So that after all a glandular cell is merely an epithelial cell in which the function of secretion is emphasized and in which the secretion which is produced is of a fluid character.

We must now pass to the consideration of the cells by which contraction is carried out. In these, of course, a considerable portion of the living substance has been modified into contractile fibres, the structure of which has already been described (Chap. III); indeed these cells are often called muscular fibres. But a **muscular fibre** and a **muscular fibril** (Fig. 2) are not identical terms. A muscular fibre is a **cell** the cytoplasm of which is usually made up of many **fibrils**, and in addition of a certain amount of residual unmodified cytoplasm in which the nucleus is situated. When the fibrils are plain or unstriped, the cell is spindle-shaped and the nucleus remains single. When, however, the fibrils are cross-striped, the fibre often becomes

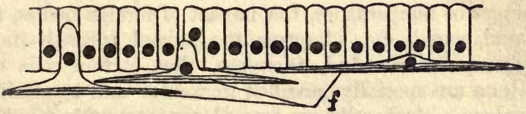

FIG. 4.—Diagram showing gradual change of epithelial cells into muscle cell *f*, the basal tails of the cells in which contractile fibrils appear.

enormously lengthened, and the nucleus divides and gives rise to many daughter nuclei, which are scattered along the length of the fibre (see Fig. 2), each embedded in a little nest of unmodified protoplasm. Now it is a most interesting fact that as we examine a large series of animals we can find every intermediate stage between a muscular cell and an epithelial cell Thus in certain sponges, which may be regarded as the lowest Metazoa, the cells forming the outer epithelium contract when irritated. When relaxed they are like flat tiles, but they gradually change into the shape of pillars as they contract, but this contraction is a slow process. If we ascend one step higher in the scale of Metazoan animals, and examine the sea-anemones, we find that in them the inner epithelium has the power of contraction, but in this case we find that each contractile epithelial cell has its base produced into a fibre, the cytoplasm in which is changed into muscular fibrils. The power of contraction is confined to this elongated base. Within the group of the sea-anemones every stage can be found between a cell which has a large epithelial portion wedged in between neighbouring epithelial cells, and a cell in which this portion is reduced to a mere button, and which consists mainly of the fibre. Such a cell is almost undistinguishable from a simple spindle-shaped muscular fibre. Contraction in the sea-anemones is far more rapid than in the sponges; and this is due to the fact that definite muscular fibrils or **myonemes** are developed in the one case and not in the other.

We conclude, therefore, that epithelial cells are the fundamental type of cell, and that glandular and muscular cells are derived and modified types. But epithelial cells can undergo other modifications which are equally important and interesting. An animal **reacts**—*i.e.* alters its behaviour in consequence of changes in its surroundings. These changes—such as changes of temperature, the impact of foreign bodies, and of light and sound, &c.—impress the animal through its outer epithelium, and we find, therefore, that certain cells of this epithelium are specially modified to receive and transmit these impressions. Such cells are termed **sensory cells** (see Fig. 3). In the simplest variety of sensory cells each possesses one or more **sense hairs** projecting from its outer surface, which can be made to vibrate by sound, or which when pressed on act as levers, to transmit pressure into the interior of the cell. The **visual cell**, which is affected by light and which forms the essential element in all organs of sight, possesses a clear glassy rod instead of a stiff hair. How the light irritates the visual cell is not known, but it is known that another kind of cell is required before the sensation of light can be received. This cell is a **pigment-cell**, and its characteristic is that it secretes granules of an intensely deeply-coloured substance termed **pigment**. Visual cells and pigment cells are placed either side by side or end to end. The suggestion has been made that the intensely rapid vibrations which constitute the waves of light decompose the pigment and produce some active chemical substance which irritates the glassy rod, but this is mere conjecture. The cells which are sensitive to odours have delicate hairs like cilia (see p. 15) projecting from their surfaces, but we have as yet no idea how the infinitesimal particles which constitute the substance of a scent affect these hairs.

In order that the impressions which reach the sensory cells may affect the animals' behaviour, they must be transmitted to the contractile and secretory cells by which that behaviour is manifested. With doubtful exceptions this transmission is never direct, but the impressions received by many sense cells are gathered into a central cell termed a **nerve cell** or **neuron,** and from it are transmitted to the glandular and contractile cells. A nerve cell has a receiving and a transmitting end. The receiving end usually consists of a group of root-like outgrowths termed **receptive dendrites,** which come into close contact with the transmitting end of another nerve cell or with the base of a sense cell. The transmitting end is a long fibre

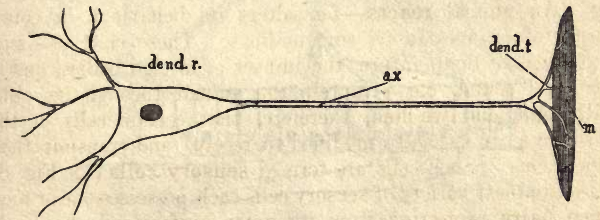

FIG. 5.—Diagrammatic figure of a neuron or nerve cell in connection with a simple muscle cell: *ax*, axon; *dend. r*, receptive dendrites; *dend. t*, terminal dendrites; *m*, muscle cell.

termed an **axon,** which eventually ends in a tuft of branches, called **terminal dendrites,** which are in close contact with the receiving end of another nerve cell, or in contact with a muscle cell or a gland cell. Now the axon may branch, and each branch terminates in the same manner as the main stem; the dendrites of the receptive end of the nerve cell may also be in contact with many sense cells. We thus see that the great function of a nerve cell *is to add together impressions received by many sense cells and to distribute them to definite contractile and glandular cells.* In this way it comes about that the animal's response to irritation does not consist of a group of isolated jerks, as it would if each sense cell communicated its impulse directly to a muscular cell, but takes the form of an orderly reaction of the whole body designed either to bring it nearer agreeable objects or to remove it farther from disagreeable ones —in a word, *the function of the nervous system is not to originate but to collect, add together, and distribute.*

When the nerve cells of such creatures as jelly-fish are studied under the high power of the microscope, every intermediate stage between an ordinary sensory epithelial cell and a nerve cell can be seen. We find some cells with receptive and transmitting ends whose bodies are still wedged between neighbouring epithelial cells: and no doubt is left in our minds that a nerve cell, like a muscular cell, a sense cell, and a gland cell, must be regarded as nothing more than a modification of an ordinary epithelial cell. We have now to consider two types of cell which cannot be regarded as modifications of epithelial

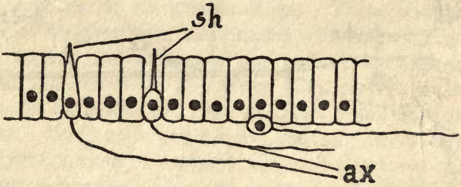

FIG. 6.—Diagram showing gradual change of an epithelial cell into a nerve cell: *ax*, axons; *sh*, sense-hairs of incipient nerve cell.

cells: these are (1) the cells of the blood and internal skeleton, and (2) the reproductive cells.

It must seem strange to the ordinary reader to associate blood and skeleton. That they are closely associated is one of the curious and unexpected discoveries of scientific zoology. The simplest type of internal skeleton is a more or less firm secretion separating two layers of epithelium; such a skeleton is found in many simple polyp-like creatures which adhere to the seaweeds on our coast. But the character of this "basement membrane," as it is termed, varies indefinitely from a thin elastic membrane to a thick gelatinous semi-fluid mass such as is found in jelly-fish. When the skeleton takes on the latter form we find in it free cells, which are capable of slow "amœboid" movement. These cells have been budded off from the epithelial cells, but they are of quite a different character from these. They have the form of little lumps of protoplasm from which finger-like or hair-like outgrowths radiate in all directions, and these outgrowths seem to be of the same nature as the outflows of cytoplasm by which simple animals like *Amœba* progress (see p. 15). But in many cases these cells appear to become stationary and to join each other by the tips of their outgrowths so as to form a

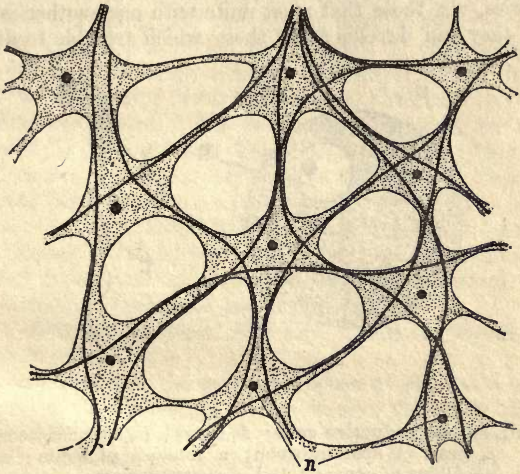

FIG. 7.—Diagrammatic representation of the formation of connective tissue. There is a network of cells joined by processes the cytoplasm of which is dotted. Connective tissue fibres are indicated by heavy lines; *n*, nuclei of the cells.

network. Along the sides of these connected outgrowths there are deposited tough fibres, and in this way a network of fibres is produced (Fig. 7). Now such a network of fibres is the fundamental basis of the construction of our own bones, tendons, and sinews. In our blood we have cells like those just described, viz. the celebrated **white corpuscles** of which so much has been written in late years, but the "skeletal substance" in which they move is the fluid of the blood. Nevertheless even in this fluid there lies latent the power of forming fibres of essentially the same character as the fibres of tendon, and this power is called into activity in case of a wound when the outflowing blood is exposed to the air. Then a tangled mass of fibres is formed which is called a **clot**.

The **reproductive cells** are those which are cast off from the parent, and which by growth give rise to a new organism. In Protozoa they are of very many kinds, but both amongst Protozoa and amongst Metazoa they may be divided into two categories, viz. those that must unite with one another in pairs before they can develop; and those which are able to develop

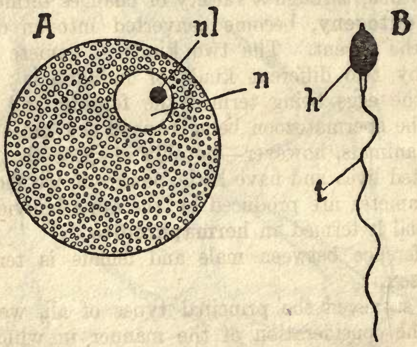

FIG. 8.—Reproductive cells: *A*, ovum; *B*, spermatozoon; *h*, head of spermatozoon; *n*, nucleus of ovum; *nl*, nucleolus of ovum; *t*, tail of spermatozoon.

directly without such preliminary union. The former variety are termed **gametes**, from the Greek word *gamé*, which signifies a marriage; the latter are termed **asexual spores**. In the overwhelming majority of the Metazoa only gametes are produced, and these gametes are invariably of two kinds, viz. comparatively large motionless gametes termed **eggs**, and small actively moving gametes termed **spermatozoa**. The egg or **ovum** is usually a rounded cell, with a considerable amount of reserve food material termed **yolk** stored up into its cyloplasm: it has a large nucleus which takes the unusual form of a rounded bladder with a small solid sphere inside it termed the **nucleolus**. The spermatozoon consists of a minute **head** which is practically nothing but a small dense nucleus and a vibratile **tail** which is really a cilium or flagellum. When the union of the two kinds of gametes, or, as it is termed, their **conjugation**, takes place, the spermatozoon plunges into the egg, breaking off its tail at the egg's surface. The head of the spermatozoon, which, as we have seen, is a nucleus, then travels towards the nucleus of the egg and unites with it. The compound cell which results from the union of these two gametes is termed a **zygote**, and the zygote, after a longer or shorter interval, proceeds to divide into a mass of cells termed the **embryo**, which, through a variety of changes termed **development** or **ontogeny**, become converted into an organism resembling the parent. The two kinds of gamete are usually produced by two different kinds of individuals; that which produces the eggs being termed the **female**, and that which produces the spermatozoon being termed the **male**. In some groups of animals, however—notably in those that lead somewhat isolated lives and have little power of locomotion—both kinds of gametes are produced by the same individual. Such an individual is termed an **hermaphrodite**.

The difference between male and female is termed a difference of **sex**.

Having surveyed the principal types of all, we must now take up the consideration of the manner in which they are combined to make up what are termed the **tissues** of the animal. Out of the tissues in turn the **organs** of the animal are constructed. The word *organ* is used to denote a part of an animal's body which is adapted to perform a particular office. Thus a man's leg is a locomotor organ, the eye a visual organ, and so on.

The word *tissue* is derived from a French word meaning a piece of cloth, and indeed it is sometimes used in English in that sense. In zoology it was first applied to the network of cell and fibres which constitutes the basis of the skeleton. This network is termed **connective tissue**, and the intercrossing fibres of which it is largely constituted do resemble the threads which form the warp and woof of a piece of cloth. Connective tissue surrounds every organ of the body and separates the different organs from one another. In fact, as Huxley has said, if we could imagine all the organs of an animal's body to be dissolved away, a complete cast of each in connective tissue would remain. When the ground substance of connective tissue in which fibres and cells lie becomes impregnated with calcareous salts, it becomes changed into what is called **bone.**

Though "tissue" is a very suitable word to describe the aggregation of cells and their products which constitute the skeleton, it is by no means an accurate description of aggregates of epithelial cells. Nevertheless it is applied in zoology to denote all aggregates of similar cells, and so we speak of epithelial, nervous, muscular, and glandular tissues. **Epithelial tisues** consist of thin sheets of epithelial cells, in most cases only one cell thick. In many cases it has been shown that each epithelial cell is connected with its neighbours by bars and bridges of cytoplasm. Where the "tissue" is more than one layer thick it is usually found that only the innermost layer is in an actively growing healthy condition. The other layers are in a decadent or dying state, and their cytoplasm is being gradually converted into dead secretion. A splendid example of this can be seen in the layers of cells which make up the outer skin or "**epidermis**" of our bodies. A moment's reflection will show us why this must be so. All protoplasm, in order to be in vigorous life, must be in immediate contact with a nutrient oxygen-carrying medium, and when there are several layers of cells only one can be so situated.

Muscular tissue consists of bundles of muscle fibres which in the vast majority of cases run parallel with one another, so that the forces occasioned by their contraction act in the same direction. Such a bundle is termed a **muscle**, it is surrounded by a sheath of connective tissue termed a **fascia**, and the individual fibres constituting the muscle are likewise separated from one another by connective tissue which penetrates between them. Only in the case of the muscular tissue which makes up the heart of man and the higher animals has it been ascertained that the muscular fibres are connected with one another by bridges of protoplasm.

Nervous tissue consists primarily of bunches or streaks of nerve cells placed near each other, but not entering into connection with one another. In many cases the axons of many nerves or neurons run parallel with one another, forming a bundle which is called a **nerve**. A single axon enclosed in its special sheath, the origin of which is doubtful, is termed a **nerve fibre**. The bodies of the neurons are arranged in many cases in clumps which are termed **ganglia** (Gr. *ganglion*, a knot), and the bands of nerve fibres connecting them are termed **commissures**.

We have already seen that gland cells are in the vast majority of cases modified epithelial cells, and it therefore follows that **glandular tissue** is merely modified epithelial tissue. In most cases, as we have seen, glandular tissue is arranged in the form of layers of epithelial cells, forming the walls of tubes. A bundle of such tubes surrounded and separated from one another by connective tissue would be a typical example of glandular tissue. Finally, the reproductive cells themselves are very often arranged in the form of tubes, and a mass of such tubes, with their supporting connective tissue, constitutes a **reproductive organ**, and might be termed **reproductive tissue**.

CHAPTER V

THE CLASSIFICATION OF ANIMALS.

It is common knowledge that there are an enormous number of sorts of animals in the world. Every one knows also that some of these sorts resemble each other closely, whilst others are widely distinct. Thus, for instance, a missel-thrush and a song-thrush are closely similar to one another; whilst there is apparently little or no resemblance between a star-fish and an elephant. When the matter is looked into closely, it is found that it is possible to arrange all animals in groups, the members of which agree in the common structural plan on which their bodies are built. Such groups are termed **Phyla**, from the Greek word signifying primarily leaf or shoot, and secondarily stock or race. The Protozoa, or animals devoid of cellular structure, constitute one such phylum; but the Metazoa consist of many phyla. It would take too long to go into the characters of all these phyla, but the general features of the most important must be pointed out. We begin with the two simplest, the **Porifera** or **Sponges**, and the **Cœlenterata** or **Polyps.** The animals included in both these groups consist of a series of branched tubes whose walls are made up of two layers of cells separated from one another by a secretion of semi-fluid consistency known as the **jelly.** This jelly often contains cells, which have wandered inwards from the outer layer, and which in many cases secrete needles of flinty or calcareous substance. This jelly, with the cells which it contains, is at once the simplest form of skeleton, and the beginning of the **blood system.** In these groups the individual is a little difficult to define. In its simplest form it is a single tube with a terminal opening. When this tube branches we regard this as a kind of **budding** or **asexual reproduction.** The branches may separate completely from the parent, but they may remain attached to it and form an individual of a higher order. In both phyla one end of the tube opens directly or indirectly to the exterior by a wide opening. In the Porifera or Sponges this opening is only used for casting out the undigested remnants of the food, and is termed the **osculum**; whilst the walls of the tube are perforated by a multitude of minute **pores** (whence

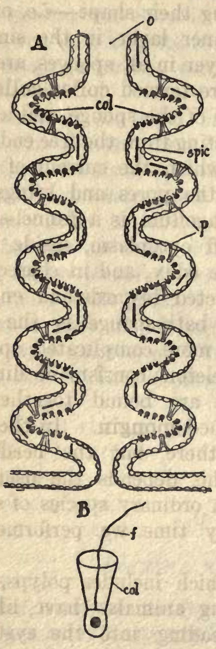

FIG. 9.—*A*, diagrammatic longitudinal section of a simple Sponge. The collar-cells and spicules are represented in black; *B*, a single collar-cell enlarged; *col* in *A*, collar-cell; *col* in *B*, collar-cell; *o*, osculum; *P*, pore; *spic*, spicule.

the name of the group) through which water carrying the food enters. The cells forming the outer layer of the sponge are flattened, but, as we have already seen (p. 25), are capable, in some cases at any rate, of changing their shape—*i.e.* of contraction. The cells forming the inner layer in the simplest sponges, and portions of the inner layer in all sponges, are very peculiar and characteristic. They are termed **collar-cells**, and each has a free end facing the cavity of the sponge, and a basal end projecting into the jelly. Projecting from the free end there is a flagellum, by the vibration of which the current of water is produced which enters through the pores and brings food to the animal. Surrounding the flagellum is a funnel-shaped **collar**, apparently composed of stiff cytoplasm, inside which the current apparently forms a little eddy, and in consequence of this eddy food particles are directed inwards and engulfed by the collar-cells. The common bath-sponge is the dried and cleaned skeleton of one of the more complicated sponges. In practically all sponges the skeleton consists of flinty or calcareous needles—in some these are bouud together into ropes by a gelatinous substance termed **spongin.** In the bath-sponge the ropes of spongin are there, but the needles or **spicules** have disappeared. On this depends the usefulness of the sponge, for were we to use an ordinary species of sponge we should lacerate our faces every time we performed our ablutions.

The **Cœlenterata**—a phylum which includes polyps, jelly-fish, sea-anemones, and coral-forming animals—have, like the Porifera, only a single opening leading into the system of tubes of which their bodies are built up; but this opening is used both for taking in food (ingestion) as well as for ejecting the undigested material. The walls of the tubes are, like those which make up the bodies of Porifera, composed of two layers of cells, the outer of which is termed **ectoderm** (*i.e.* outside skin) and the inner, **endoderm** (*i.e.* inside skin), but the tubal walls are not perforated by pores, nor does the inner layer consist of collar-cells, nor do the Cœlenterata obtain their food by causing currents in the water. On the contrary, the terminal opening of each tube is used for taking in food, and is termed the **mouth.** It is typically surrounded by a ring of **tentacles**, by means of which prey is captured and pushed through the mouth into the interior of the tube, where it is digested. These tentacles are muscular prolongations of the body capable of exceedingly quick movement, and containing in their outer cells numerous **stinging-cells** or **cnidoblasts.** These stinging-cells are just as characteristic of Cœlenterata as the collar-cells are of Porifera. Each cell has a little projecting process or **sense-hair** for perceiving stimuli: whilst embedded in its cytoplasm is a little bag, termed the **nematocyst,** which contains a clear fluid, and one end of which is tucked inwards into its interior like the turned-in toe of a stocking. This end is very long, and is termed the **thread.** When the animal is irritated, the cells forming the outer layer of the body contract, and squeeze the stinging cell. As a consequence the nematocyst of the stinging-cell is squirted out like a seed from a ripe orange, and the inturned end or thread of the nematocyst, is also turned inside out. This thread is coated with a poisonous substance, and it penetrates the bodies of the animals on which the Cœlenterate preys, and stuns and kills them. In most cases the thread is incapable of penetrating the human skin, but in the case of some of the larger jelly-fish it can pierce even this, and then the sufferer experiences a burning pain.

"**Coral**" is a general name given to the hard skeleton of Cœlenterata when this is present: it is formed in many different ways. The beautiful red coral, which is used to form bracelets and necklaces, consists of needles of calcareous matter cemented together; these needles are formed just like the spicules of sponges by cells which have migrated into the jelly from the outer layer of cells. The coral, which forms the masses of which coral reefs mainly consist, appears to be formed as an external exudation from the cells of the external layer. In this way cups or **thecæ** are formed, in which the bodies of the Cœlenterate individuals are contained. To the fanciful eyes of the ancients these thecæ resembled flowers, and so the legend arose that the branches of coral were a subaqueous flowering plant, which became transformed into stone when it was exposed to the air.

Next in degree of complication of structure to the Cœlenterata comes the phylum of **Platyhelminthes** or **Flat-worms.**

The word "Worm" is a merely popular term which is used to denote any wriggling creature of simple structure, and amongst the so-called "Worms" are included members of many different phyla. The Flat-worms agree with Cœlenterates in possessing a mouth which is used both for ingesting food and for ejecting waste material, and in having as the basis of their structure a ramified set of tubes lined by an internal layer of cells and contained within an outer layer or skin. But between skin and internal layer is contained a mass of cells which is differentiated into definite muscular and nervous tissues to a degree which never occurs in any Cœlenterate; and in particular there are aggregations of nervous matter constituting two large ganglia termed the **brain**, and two cords or bands along the sides of the body. We are thus presented with a definite concentration of nervous matter which is termed a **central nervous system**; and such a system, consisting of the **brain** and the two cords, is found in no Cœlenterate and is characteristic of all Platyhelminthes. The phylum Platyhelminthes includes many kinds of animals which live in the interior of other animals,

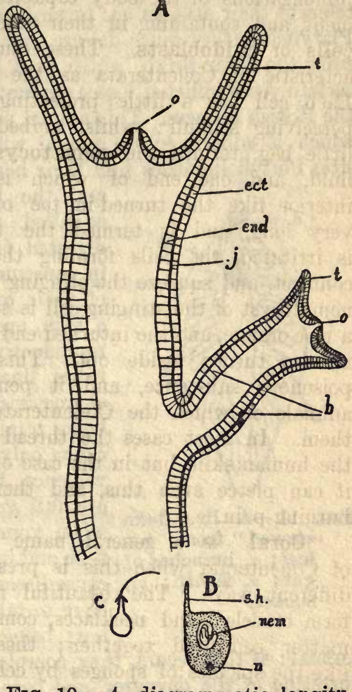

FIG. 10.—*A*, diagrammatic longitudinal section of a simple Cœlenterate with a bud attached; *B*, a stinging-cell (cnidoblast) with a nematocyst inside; *C*, a discharged nematocyst; *b*, bud; *ect*, ectoderm; *end*, endoderm; *j*, jelly; *n*, nucleus; *nem*, nematocyst; *o*, mouth; *s.h.*, sense-hair; *t*, tentacle.

and derive their nourishment from the tissues of the animals which they infest. Such predatory forms are termed **parasites**; and the unfortunate animals which have to tolerate their attacks are termed **hosts.** Some of the parasitic Platyhelminthes cause disease and death to their hosts, in particular the **liver-fluke,** which lives in the liver of sheep, has in certain years inflicted losses amounting to millions of pounds on the British farmers. This animal possesses suckers, by means of which it adheres to the animal which it infests. Other parasitic Platyhelminthes find their home in the intestines of man and the higher animals—these, the so-called **tape-worms,** live on the digested food of their hosts, and have in consequence no digestive apparatus of their own: they consist merely of a skin, enclosing nerves, muscles, and reproductive cells—the inner set of tubes lined with digestive cells, so characteristic of other Platyhelminthes, being totally absent. These creatures cause only a minor amount of inconvenience to their hosts when they are full grown; but many of them, when young and immature, infest the flesh and internal organs of animals and cause disease and death. These parasites have to take their chance of their first host being devoured by a carnivorous animal: if this occurs, they complete their development in the intestine of the devourer, and become adult. One tape-worm, in its immature stage, infests the brain of domestic animals, and causes the disease called **staggers**—another attacks the liver of domestic animals and of man himself, and causes a dangerous tumour which is often fatal.

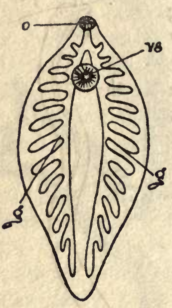

FIG. 11.—A liver-fluke viewed from below; *g*, branches of gut; *o*, mouth; *vs*, sucker.

Another phylum whose members are termed "worms" is the **Nemertinea.** In these animals we also find a type of structure which consists of a skin and internal digestive tube, and between them a mass of muscular tissue. There is likewise a central nervous system consisting of two large ganglia termed a brain and two lateral cords. But in one point there is an enormous advance over the structure exhibited by the Platyhelminthes; the digestive tube has two openings, one in front called the **mouth**, used for taking in food, and one behind termed the **anus**, for rejecting undigested material. The Nemertinea are further distinguished by possessing a kind of protrusible trunk at the front end of their bodies, which when not in use is retracted into a sheath. This trunk is termed the **proboscis**, and it can be rapidly shot out and rolled round the victims on which they prey; for the Nemertinea are active predatory animals.

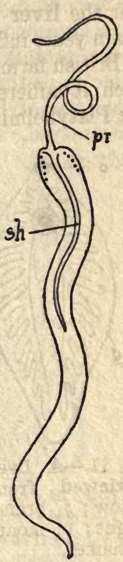

FIG. 12.—A Nemertine worm viewed from upper surface; *pr*, proboscis; *sh*, sheath of proboscis.

Another phylum whose members are termed "worms" is that of the **Nematoda** or **Thread-worms.** These animals are in the great majority of cases parasites; they are practically ubiquitous, and are of enormous economic and medical importance. Like the Nemertinea, and indeed all the other groups which we shall still have to consider, they possess both mouth and anus. Their leading feature is the extreme simplicity of their anatomy. The digestive tube is simple and straight, without complications. The muscular system consists of a single layer of longitudinal muscles; outside these comes the skin, which consists of a layer of cytoplasm with scattered nuclei, in which separate cells cannot be distinguished. This skin gives rise to the most characteristic feature of the group, viz. a thick, smooth, glistening **cuticle,** *i.e.* a sheath of dead secretion which is produced by the transformation of the cytoplasm of the skin. This cuticle is very elastic, and, as the young animal grows in length, it stretches; but its elasticity has limits—it is eventually burst and cast off, and the animal then grows rapidly in length, and forms a new cuticle by renewed secretion. This process, which is termed moulting, or **ecdysis,** occurs four or five times in the animal's life.

Between the muscular layer and the digestive tube or **gut** there exists a space, or rather a set of inter-communicating spaces, which we may term the **body-cavity.** They are filled with a clear fluid which surges about as the animal wriggles; in this fluid are contained the products of digestion which have been exuded from the digestive cells, and the whole thing is the prototype of the "**blood**" of the higher animals. In order to distinguish it from body-cavities of a different kind, this type of body-cavity, the simplest and the first we have encountered, is termed a **primary body-cavity,** or a **blood body-cavity** or **hæmocœle.** Nematoda vary in size from

FIG. 13.—A Nematode worm; *o*, position of mouth.

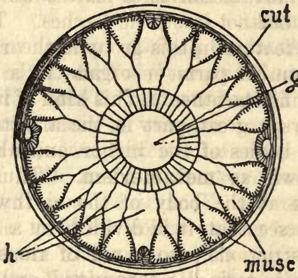

FIG. 14.—Diagrammatic cross-section of a Nematode worm; *cut*, cuticle; *g*, gut; *h*, hæmocœle or primary body-cavity; *musc*, muscle cells.

minute microscopic "worms" to creatures a yard long. These last, the dreaded **Guinea Worms** of the tropics, infest the skin and underlying tissues of men and animals, and cause dangerous sores and ulcers. It has been suggested that they may have been the "fiery flying serpents" which attacked the wandering Israelites. The only safe way to extract them is to tie their protruding ends to a stick, and then slowly and gently to wind them round this. If sudden extraction be attempted, the worm breaks, and the portion left in the sufferer dies and decays, and causes poisoning and death. It is therefore possible that the famous "serpent on the pole" exhibited by Moses was an object-lesson to his followers as to how the scourge was to be dealt with. Many thread-worms infest the flesh of the pig, and one microscopic form escapes when this flesh is eaten and takes up its abode in the intestine of the flesh-consumer. Thence it burrows through the walls of his stomach into his flesh, causing in its passage the severe and often fatal disease called **Trichinosis**, which has wrought great havoc in Germany, where pig-flesh is often eaten in an imperfectly cooked condition.

Still another phylum of "worms" exists, which are termed **Annelida** or **Ringed-worms**. This group includes our familiar earthworms, and the innumerable forms of marine worms, and, last but not least, the leeches. The leading feature in this group is the repetition of similar parts or organs in a line one behind the other. This kind of repetition plays a great part in the architecture of the bodies of the higher animals, and is known as **metamerism**. Thus, if we look at the body of the earthworm, we can see that it is divided by a series of constrictions into a set of rings. Each ring is termed a "**somite**," and in each we find embedded eight bristles. Each somite contains a pair of ganglia of the central nervous system. The nervous system is indeed one of the most characteristic features of the Annelida. It consists of a pair of ganglia, closely connective, lying above the digestive tube in front and termed the brain; and a series of pairs of closely connected ganglia lying beneath the gut—one pair, as we have already said, being situated in each somite. These lower ganglia are connected with one another by longitudinal bands of nervous matter or **commissures**. The whole knotted chain is termed the **ventral nerve-cord**, and this cord is connected with the brain by a "**nerve-collar**" which embraces the digestive tube in front. The under side of an animal is called "**ventral**" (Lat. *venter*, the belly); the upper side is termed "**dorsal**" (Lat. *dorsum*, the back). In the Annelida we meet for the first time with a **secondary body-**

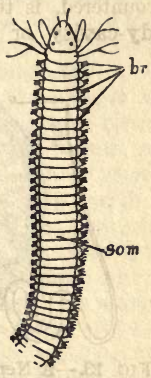

FIG. 15.—Upper view of Annelid worm; *br*, metamerically repeated bristles; *som*, a somite.

cavity or **cœlom.** This cœlom consists of a series of ring-shaped cavities, one in each somite, surrounding the gut, and separating it from the skin. A rough model of the earthworm's body could be made by taking a piece of gas-pipe to represent the gut, and slipping over it a series of hollow rubber rings and then enveloping the whole in a linen casing. The linen casing would represent the skin, and the rubber rings the cœlom. As this model indicates, the cœlom is not merely a series of gaps intervening between other organs, but consists in reality

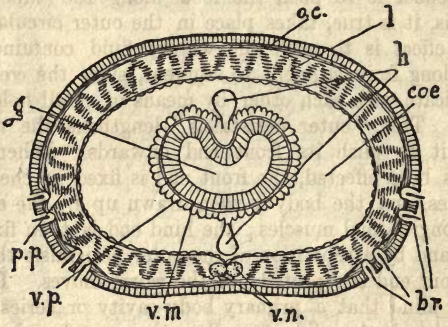

Fig. 16.—Diagrammatic cross-section of an Annelid worm; *br*, bristles; *coe*, cœlom or secondary body-cavity; *g*, gut; *h*, blood-vessels representing the hæmocœle; *l*, longitudinal muscles; *o.c.*, outer circular muscles; *p.p.*, parietal peritoneum; *v.m.*, visceral muscles; *v.n.*, ventral nerve-cord; *v.p.*, visceral peritoneum.

of a series of sacs, each with its own inner and outer wall. The outer wall abuts on the skin, and is known as the **parietal peritoneum,** whilst the inner wall is pressed against the gut and is termed the **visceral peritoneum.** As the baby worm grows, cells belonging to both walls become transformed into muscular fibres. Those belonging to the parietal layer are arranged longitudinally, and form the **parietal** or body **musculature,** whilst those belonging to the visceral layer form a series of bands encircling the gut, and are termed **visceral muscles.** In addition there are outer circular muscles derived from the cells of the skin which lie outside the longitudinal muscles. One purpose of the cœlom is to allow the gut and the skin to be moved independently of one another; whereas in the "worms" which we have heretofore considered, the whole body moves in one piece, so to speak, an Annelid might almost be considered as an animal within an animal, for the motions of the gut go on independently of those of the outer skin. The muscles of the gut undergo contraction one after the other in such a way as to cause a wave of contraction to pass along the tube. This wave motion is called **peristalsis**, and its effect is to push the food along the tube. Similar peristalsis, it is true, takes place in the outer circular muscles, and its effect is to push the watery fluid contained in the cœlom along from segment to segment, since the cœlomic sacs communicate with each other by means of small holes beneath the gut. This "outer peristalsis" lengthens the worm, and enables it to push its front end onwards. When progress has thus been effected, the front end is fixed in the earth by its bristles, and the body is then drawn up by the contraction of the longitudinal muscles; the hind end is then fixed in the ground, and by a repetition of the outer peristalsis the advance of the front end is repeated; so the worm moves. It must be borne in mind that a primary body-cavity or series of blood-spaces exists in Annelida as well as the secondary body-cavity. This primary body-cavity takes the form of a series of branched tubes which contain a red fluid, and which are distributed to all the organs of the body. This red fluid is, of course, the "**blood**" of the worm. Nearly all worms of the phylum Annelida are burrowers at some stage of their existence; the majority burrow in the sand and mud at the bottom of the sea, and only rise to the surface when they have ripened their reproductive cells and are about to discharge them. At such times they often appear in countless numbers, and furnish an important source of food-supply to the natives of the Pacific islands, who call them "Palolo." These reproductive cells are produced from the walls of the cœlomic sacs, and in some few cases are only discharged by the breaking of the body; but in most cases definite openings, termed **reproductive pores** or **cœlomiducts**, exist, which allow of the discharge of the reproductive cells. No annelid stands convicted of causing harm to man, his domestic animals, or his crops; on the contrary, as Darwin has shown, the earthworm acts as nature's ploughman, since it eats its way into the earth, and, after having filled itself with clay, returns to the surface and voids there the clay which it has brought from the depths. The marine worms form an indispensable food-supply for our edible fish.

When we leave the creatures usually termed "worms" in order to survey the higher groups of animals, we naturally begin with the phylum of the **Arthropoda**, since the animals belonging to this group show a good deal of general resemblance to the Annelida. They show a division of the body into successive rings or somites, and a very similar central nervous system to that possessed by the Annelida, consisting of a brain, collar, and ventral nerve-cord. The great characteristic of the Arthropoda is the existence of a thick external cuticle produced by the cells of the skin. A very thin and delicate cuticle of this kind is found amongst Annelida, but in Arthropoda it becomes so thick and hard as to constitute a veritable armour; and as the animal grows this cuticle is constantly shed and re-formed. Moulting or "**ecdysis**" occurs much oftener than amongst Nematoda, because the cuticle is not expansible. Encased in such an armour, motion is only possible to the Arthropoda through the existence of folds in the skin where the cuticle remains soft and flexible, and which act as hinges. These flexible spots are termed "**arthrodial membranes,**" and the hard places "**sclerites.**" More or fewer of the somites of the body carry paired outgrowths or "**limbs,**" and the characteristic Arthropod way of moving is not by wriggling or peristalsis like an Annelid, but may best be described as a process of *rowing* itself along by these limbs if it be an inhabitant of water, or of walking on them if it be a land-dweller. Some of these limbs in the neighbourhood of the mouth are generally modified for crushing the food, and are termed "**gnathites**" or jaws. One of the most important internal differences between Annelids and Arthropoda is the suppression of the secondary body-cavity or cœlom in Arthropoda and the enlargement of the primary body-cavity into a wide series of spaces. The cœlom is usually large and conspicuous in the embryos of Arthropoda, but as the animal grows it fails to keep pace with the growth of other parts, and in the adult is represented by small sac-like cavities, from the walls of which the reproductive cells arise.

The Arthropoda are an enormous phylum, and include more than half a million kinds of animal, of which accurate descriptions have been published. They affect and limit the life of

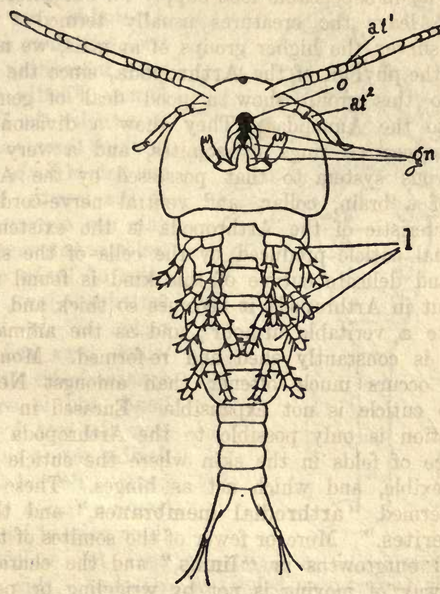

FIG. 17.—A water-flea as an example of Crustacea viewed from below; *at*[1], first antennæ; *at*[2], second antennæ; *gn*, gnathites; *l*, walking legs; *o*, mouth.

man more than any other group of the animal kingdom. Leaving out of account minor divisions, the Arthropoda are subdivided into three main groups. We have first of all the **Crustacea**, which are almost all aquatic, and which have the first two pairs of limbs, which are situated in front of the mouth, transformed into delicate feelers or **antennæ**, and the following two pairs, and often others, transformed into jaws (gnathites). Then come the **Arachnida**, in which the first pair of limbs is a small pair of claws termed **chelicerae**, and this is the only pair which is in front of the mouth; the following pairs of limbs may have their bases slightly broadened and roughened so as to assist in chewing, but they are also used for walking. Most Arachnida are terrestrial, but there are some most interesting aquatic forms. Finally, we have to consider the **Insecta**, in which there is also only one pair of limbs in front of the mouth, but this pair are converted into feelers or antennæ. Three pairs of limbs are converted into jaws, and the region of the body to which jaws and feelers are attached is termed the **head**, and is separated from the rest by a thin flexible region called the **neck**. Behind the neck comes a region to which three pairs of long limbs used for walking are attached: this is the **thorax**, and it consists of three segments. The last two of these in many cases bear flat outgrowths used for flying, which are termed "**wings.**" Following the thorax comes a region consisting of nine or ten segments devoid of appendages, which is termed the **abdomen.** The word "insect," which literally means "cut into," refers to the striking differentiation of the body into these three regions. The Insecta breathe by means of air tubes which ramify through their bodies, and they are typically

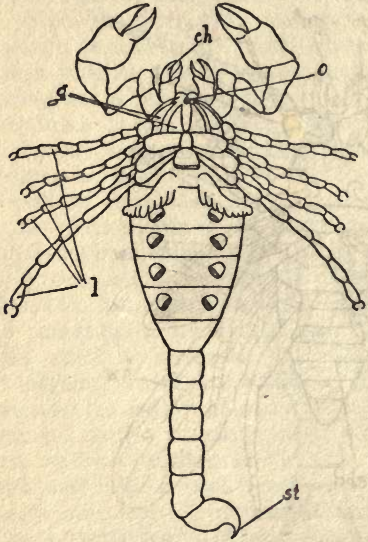

FIG. 18.—A scorpion as an example of Arachnida viewed from below; *ch*, chelicerae; *g*, chewing processes borne at the bases of *l*, the walking legs; *o*, mouth.

denizens of the earth and air. The few that descend to water take their air-tubes with them, and lead an existence which may be more aptly compared to that of a diver than to that of a purely aquatic animal like a fish. The group Insecta include all the myriad forms of flies, beetles, ants, bees, wasps,

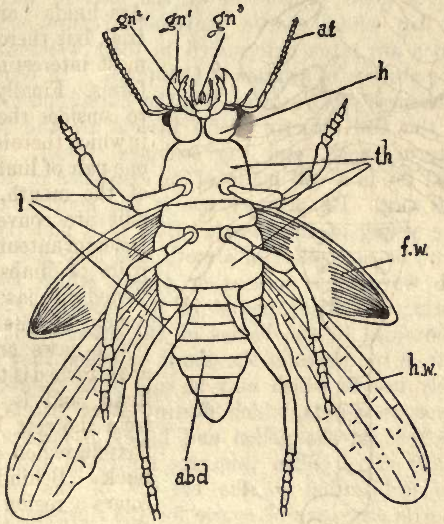

FIG. 19.—A beetle viewed from below as an example of Insecta; *at*, single pair of antennæ; *abd*, abdomen; *f.w.*, fore wing; gn^1, gn^2, gn^3, the three pairs of gnathites; *h.w.*, hind wing; *h*, head; *l*, walking legs; *th*, thorax.

butterflies, moths, bugs, locusts, grasshoppers, &c. Spiders and mites, although popularly termed insects, really belong to the Arachnida.

The Crustacea include all our crabs, lobsters, shrimps, cray-fish, and the minnte "water-fleas" which are found in our streams aud ponds, as well as the myriads of similar forms which are fouud in the sea. Speaking broadly, the Crustacea are never harmful to man: some of them, indeed, are directly useful in furnishing food. Everyone knows how universally shrimps are consumed, especially by the poor, and on the coast of a small province like New Brunswick there are 800 institutions for "canning" lobsters. But the principal importance to man of the Crustacea lies in the fact that they form a great proportion of the food of fish, and the shoals of fish whose erratic movements cause such distress to fishermen are often determined in their wandering by the presence or absence of swarms of Crustacea. In contrast with the harmlessness of Crustacea lies the harmfulness of Insecta. Amongst the few directly useful insects are the honey bee, the silkworm, moth, and the cochineal insect. Honey is food stored up in a cell made of an exudation of the insect's skin called wax. Its primary use is the nourishment of the developing young of the insect. Silk is a material secreted by the grub or caterpillar of a moth, and is formed as threads which are woven into a case or cocoon which shelters the insect during a critical period in its growth. Cochineal is a stuff contained in the bodies of the insects, and produced by them from the juices of the plants on which they live.

The only insects which may be said to be indirectly useful are carnivorous insects, which destroy other insects, and such insects as feed on the pollen and honey of flowers and thus inadvertently carry pollen from one flower to another and so effect the fertilisation of the egg-cell of the plant. This fertilisation is necessary of course for the ripening of the fruit and its contained seed. Insects are, in fact, man's great competitors for the enjoyment of the fruits of the earth, and when their numbers increase unduly man runs a great risk of starving. Blood-sucking insects render life almost intolerable in many regions of the tropics, and it has been recently proved that, in addition to depleting the strength of their victims by constant drafts on their blood, they implant in them the germs of parasitic protozoa, which run riot in their blood and cause fever and death. The problem of the successful exploitation of the tropics, which are the naturally richest regions of the earth, is largely a problem of how to fight and conquer the insect life which luxuriates there. It is little wonder that the study of insects has acquired an importance which has raised it to the rank of a distinct science. It is termed **Entomology**, and it is in this branch that the practical importance of zoological science to the life of man has been most effectively demonstrated. Arachnida are very few in numbers compared to insects, but most of them are distinctly harmfnl to man, from the scorpion with its stinging tail, which lies in wait for the bare-footed inhabitant of the tropics, to the mite popularly termed the harvest bug, which burrows under the skin of the reaper's legs as he mows the corn, and causes painful boils. The spider perhaps merits tolerance as a destroyer of insects.

Next to the great phylum of Arthropoda comes the phylum of **Mollusca**, familiarly known to all as **shell-fish.** This phylum includes also the octopus and cuttlefish, and amongst the latter are included some of the largest animals living. Like the Arthropoda, the Mollusca are characterised by their cuticle; but whereas amongst Arthropoda the cuticle envelops the whole body like an armour, the cuticle of Mollusca, termed the **shell**, is produced only by a limited region of the skin termed the **mantle.** The rest of the skin remains soft, is in most cases covered with cilia, and is provided with numerous glandular cells which produce mucus or slime. It is to this last circumstance that the group owes its name, for Mollusca is derived from the Latin *mollis*, soft. The mantle or shell-bearing region usually projects as a free flap, termed the **mantle-lobe** or **mantle-fold**, from the surface of the body, and the rest of the body can usually be withdrawn within the embrace of the mantle and overlying shell, and so the animal is protected against its enemies. In contrast with the limbs of Arthropoda, the organ of locomotion of Mollusca is a thick muscular mass on the under surface of the body, termed the

Fig. 20.—Side view of a living cockle as an example of the division of Mollusca called Pelecypoda; *f*, foot; *m*, mantle; *o*, o^1, two posterior openings between joined mantle-flaps; *s*, shell.

foot, by the aid of which creeping movements are carried out. So far as the internal organs are concerned, Mollusca are remarkable for the absence of metamerism. Both primary and secondary body-cavities are developed; but the former includes most of the spaces which intervene between the skin and the gut, whilst the latter forms the genital sacs and a space called the **pericardium** which surrounds the heart. In this last feature lies another contrast between Mollusca and Arthropoda, for in the latter group there is also a space called the **pericardium** surrounding the heart; but this space in Arthropoda is part of the primary body-cavity, and the heart opens into it by open slits called **ostia**. Mollusca are

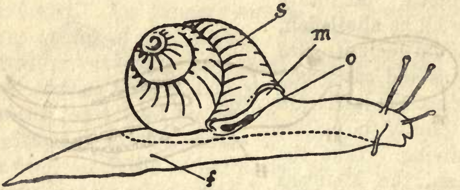

FIG. 21.—Side view of a living snail as an example of the division of Mollusca called Gastropoda; *f*, foot—the dotted line, as in Fig. 20, shows the upper limit of the muscular portion; *m*, mantle; *o*, opening between mantle and body; *s*, shell.

divided into groups according to the size and shape of what we may term the dominating organs, *i.e.* the **mantle, shell**, and **foot**. Thus in one large division the mantle is represented by two flaps situated to the right and left of the animal's body, and the shell consists of stiff right and left valves united by a median horny flexible piece termed the **hinge**. This is so arranged that when it is uncompressed it holds the two valves of the shell apart from one another; but when the animal is alive and is alarmed, it can withdraw the foot and lower part of the body within the embrace of the valves, and can then hold the two valves tightly pressed together by the contraction of a powerful muscle. The foot in this group is shaped like an axe or wedge, and the animal when alive slowly ploughs its way through mud or gravel.

The scientific name **Pelecypoda** (Gr. *pelekus*, an axe) is derived from this circumstance, whilst the popular name bivalve has reference to the shell. In another group the mantle is a circular flap surrounding the body and the shell is at first a cap, but as the animal grows both mantle edge and shell become lengthened and deepened, and this process goes on unevenly, so that the cap becomes twisted into a spiral. The foot has a flat surface, by means of which the animal crawls over the rocks and stones on which it lives. Here again the scientific name **Gastropoda** (*lit.* belly-foot) is derived from the shape of the foot, whilst the popular name **univalve** refers to the shape of the shell. Lastly, in the **Cuttle-fish** the

FIG. 22.—Side view of a cuttle-fish swimming as an example of the division of Mollusca called Cephalopoda; *ff*, fore-foot produced into arms bearing suckers; *hf*, hind-foot or funnel—the dotted line shows upper edge of foot; *m*, mantle; *s*, concealed shell.

mantle is also a circular flap surrounding the body, but the shell, primarily, as in Gastropoda, a cap, is usually concealed in the mantle which grows up at its sides and closes over it. The foot is in two divisions, the **fore-foot** and the **hind-foot.** The former has grown up so as to surround the front part of the body like a collar, and the edges of this collar are drawn out into strap-like **muscular arms** beset with suckers, which are most formidable weapons for attack and defence. With these arms it seizes and securely holds its prey; and its mouth is armed with a strong beak with which it tears the prey to pieces. The hind-foot consists of a vibrating muscular tube termed the **funnel** through which a strong stream of water is driven backwards, by the recoil of which the animal is driven forwards. The scientific name **Cephalopod** (head-foot) which is applied to this division of Mollusca is derived from the shape of the fore-foot. The **bivalves** include all the shellfish known as mussels, clams, scallops, and oysters. Amongst the **univalves** we reckon the land and sea snails, the periwinkles, whelks, top-shells, and cowries of our shores, whilst the **Cephalopods** include the rare tropical Pearly Nautilus—the only living form belonging to this group which has a spirally coiled external shell—the squid, the calamary, and the octopus which haunts the submarine holes in rocks all round our coasts. To the same group belongs the enormous squid of Nova Scotia, in which the body is ten feet long and the "arms" (*i.e.* the divisions of the fore-foot) may be 40 feet long. The greater number of the Mollusca are neither harmful nor useful to man, but a few are used for food. The most prized and in every way the most valuable is the oyster—a bivalve in which the muscular foot is absent, and which on that account is much more edible than its allies; but the mussel (*Mytilus*), the cockle (*Cardium*), and the scallop (*Pecten*) are extensively eaten by the poorer classes. In America the hard-shelled clam (*Venus mercenaria*) and the soft-shelled clam (*Mya*) are esteemed as delicacies. Amongst univalves the periwinkle (*Littorina*) is the only one which is used for food in this country, but in France the snail is consumed, and is actually bred for consumption since it is regarded as a delicacy. Amongst cuttle-fish the common squid (*Sepia*), the calamary (*Loligo*), and the octopus are all used for food in Italy: but the secondary usefulness of Mollusca as bait to capture the valuable edible fish far exceeds their direct value as food. In this country countless thousands of the Limpet (*Patella*), perhaps our commonest univalve, are used for this purpose. In North America the soft-shelled clam (*Mya*) and various forms of cuttle-fish (*Loligo*, *Ommastrephes*, &c.) are used. The struggle to obtain these valuable forms of bait has already led to international complications between the British Colony of Newfoundland and the United States of America and has also led to bad blood between the provinces of the Dominion of Canada, since the people of New Brunswick have accused those of Nova Scotia of ravaging their clam-beds.

Next to the Mollusca we must devote a few words to the phylum **Brachiopoda.** These are represented by few species at the present time; all are inhabitants of the sea, and nearly all of them live at the bottom of comparatively deep water. They are of no economic importance whatever. But in past time, as evidenced by their fossil remains, they must have swarmed in the seas, and in certain places on the coast of the West of Ireland every stone which is lifted from the beach contains a fossil Brachiopod. They are therefore familiar to all collectors of fossils, and since their bodies were protected by two shelly valves they present a considerable resemblance to bivalve Mollusca; and it is somewhat of a shock to learn that

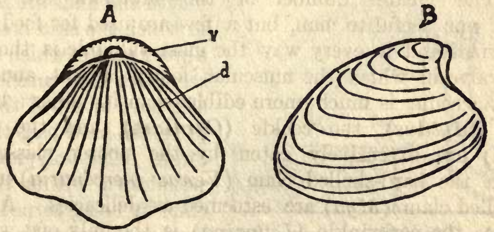

FIG. 23.—*A*, shell of Brachiopod viewed from above to compare with *B*, the shell of Pelecypod or bivalve Mollusc viewed from the side; *d*, upper and anterior valve of Brachiopod shell; *v*, lower and posterior valve.

the scientific zoologist regards them as members of a distinct phylum with no relation to the Mollusca whatever. An examination of tne living forms shows that the two valves of the Brachiopoda are upper or **dorsal** and lower or **ventral**, not right and left as in Mollusca; that there is no foot, but that a stalk arises from the posterior part of the body by which the animal is permanently anchored to the rock on which it lives. Further, the secondary body-cavity is exceedingly wide and spacious, whilst the primary body-cavity or blood-system is very small and difficult to detect. In fact the internal organisation of a Brachiopod has more resemblance to that of an Annelid than to that of a Mollusc; and in this connection it may be mentioned that in the edges of the mantle-folds of Brachiopods there are embedded bristles similar to those found in the skin of most Annelida.

Another phylum which deserves a brief mention is that of the **Polyzoa.** These are small animals of almost microscopic size, which like the Cœlenterata form colonies by budding. They are however widely different from Cœlenterata, to the colonies of which their colonies present some external resemblance. Each individual of a Polyzoan colony has, it is true, a mouth surrounded by tentacles, but it possesses a complete alimentary canal with mouth and anus surrounded by a well-developed secondary body-cavity. The body of each individual of the colony consists of two portions: a part in which the mouth and anus are situated, in which the skin is soft, and a lower part in which the skin secretes a hard cuticle. The soft part is called the **polypide,** the hard part the **zoœcium.** The polypide can be withdrawn within the zoœcium by being turned outside in when the animal is alarmed. The masses of zoœcia form delicate lace-like encrustations on the inner side of old shells, &c. The remains of the zoœcia of extinct Polyzoa are amongst the commonest of fossils.

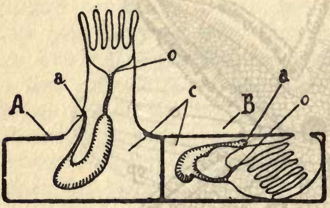

FIG. 24.—Diagram showing two individuals of Polyzoon colony. *A*, with extended, and *B*, with retracted, polypide; *a*, anus; *o*, mouth; *c*, cœlom.

We now turn to a phylum which includes much more familiar animals than the Polyzoa. The name of this phylum is the **Echinodermata,** and the animals included in it are the star-fish, sea-urchins, and brittle-stars of our coasts. Two other less familiar groups likewise belong to the Echinodermata, viz. the delicate feather-stars and the sausage-shaped sea-cucumbers. All are inhabitants of the sea, and all are characterised by having their organs arranged in radiate symmetry around the mouth. By **radiate symmetry** is meant that, instead of the organs being in pairs, as they are in ourselves and in most of the phyla which we have heretofore discussed, they are arranged in Echinodermata like the spokes of a wheel round the hub. In Echinodermata there is a complete digestive tube, surrounded by a spacious secondary body cavity: of the primary body-cavity there are only traces. Surrounding the mouth there is a ring-shaped tube containing a watery fluid: this tube, which is in reality a special section of the cœlom, is termed the **water vascular system** or **hydrocœle.** It is perhaps the most characteristic organ of

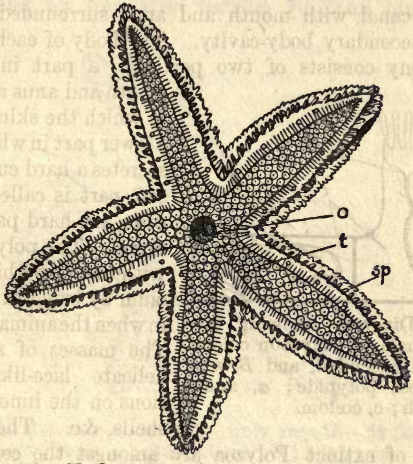

FIG. 25.—Under view of common star-fish as an example of Echinodermata; *o*, mouth; *sp*, spines; *t*, tube-feet.

the Echinodermata. It gives off a number (usually five) of branches which radiate outwards. In star-fish, brittle-stars, and feather-stars these radiating tubes are supported by arm-like outgrowths of the body; but in the globular or disc-like sea-urchins and in the sausage-shaped sea-cucumbers they run back over the surface of the body like meridians of longitude on a school globe. These tubes in turn give off to right and left, paired outgrowths which project externally as tentacles, and which form the sensory organs of the animal. They are termed "**tube-feet.**" In most star-fish and many sea-urchins and sea-cucumbers the tips of these tube-feet are terminated by circular discs, which act like suckers and enable the animal to adhere to the surface over which it is passing, and the animal literally walks on them. From the ring-canal of the hydrocœle, in the interval between two of the radiating canals, there arises a vertical canal termed the **stone-canal** which terminates in a plate pierced with pores on the upper surfaces of the animal. This plate is called the **madreporite**: its pores are lined by ciliated cells, and its purpose is to

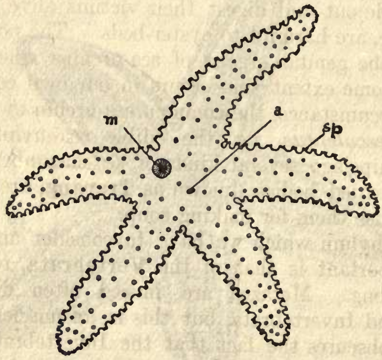

Fig. 26.—Upper view of common star-fish as an example of Echinodermata; *a*, anus; madreporite; *sp*, spines.

introduce fresh supplies of water into the hydrocœle. Next to the water-vascular system, the skeleton of Echinodermata constitutes their most distinctive feature. In Sponges and in some Cœlenterata the skeleton consists, as we have already seen, of needles of calcareous or flinty matter embedded in the jelly which intravenes between skin and digestive tube, but in all the other phyla which we have so far discussed and in most Cœlenterata the skeleton is of the nature of an exudation or secretion from the external surface of the skin. In Echinodermata, on the contrary, the skeleton consists of calcareous plates embedded in the jelly beneath the skin, but outside the outer wall of the coelom. These plates have resulted from the calcification of the ground-substance of connective tissue, *i.e.* from the deposition in it of salts of lime. As a consequence these plates are porous; they are indeed scaffoldings rather than solid masses of lime, and in their interstices we find the characteristic amoeboid cells of connective tissue. In consequence of possessing such a skeleton, Echinodermata are amongst the commonest of fossils. Their economic importance is extremely slight. The star-fish feed on bivalve mollusca, whose valves they forcibly wrench apart by pulling on them with their suckers; they then turn their stomachs inside out and digest their victims alive. Star-fish, in consequence, are harmful to oyster-beds. The poorer classes in Italy eat the genital organs of sea-urchins when they are ripe, and to some extent this occurs in our own country also, and to this circumstance the common sea-urchin owes its name of *Echinus esculentus*, *i.e.* the edible sea-urchin. In the Malayan Archipelago several kinds of sea-cucumber are fished for and their dried bodies, known as **Trepang**, are sold to the Chinese who use them for making soup.

The last phylum which we have to consider and infinitely the most important is that of the **Vertebrata**, to which we ourselves belong. Metazoa are indeed often divided into Vertebrata and Invertebrata, but this is an unscientific classification and obscures the fact that the Invertebrata which we have been discussing consist of many distinct phyla; whilst all the animals classed as Vertebrata exhibit the same fundamental type of structure and constitute a single phylum. The chief characteristics of Vertebrata are three, viz.: (1) There is an internal skeleton known as the **backbone** which runs the whole length of the animal, beneath the central nervous system, but above the digestive tube or gut; (2) the central nervous system is situated near the upper or "**dorsal**" surface of the animal, and has the form of a tube running along the length of the animal; (3) the front part of the digestive tube communicates with the exterior by means of clefts or pores. In aquatic forms these clefts serve to get rid of the surplus water which the animal swallows with its food; in these they are termed **gill-clefts**, but in land forms they exist only in the very young animal and close up when it becomes adult. The word

vertebra, which literally signifies something turned in a lathe, is applied to the disc-like segments of which the backbone of the higher Vertebrata is made up, but in all Vertebrata in the early stages of development, and in the simpler forms throughout life, the "backbone" consists of a gelatinous string termed the **notochord** (*lit.* back-string). The vertebræ are formed later round this string, and it is then more or less absorbed. The hollow nerve-tube has in the vast majority of cases a great hollow expansion at its front end termed the **brain.** In the higher Vertebrata the walls of this expansion become very thick and its cavity small. The Vertebrata include ourselves and the animals which most resemble us, viz. the warm-blooded hairy quadrupeds or **mammals**; but they also include the **birds, reptiles, amphibians**, and **fishes**, and moreover a group of forms which the older naturalists classed as Invertebrata, viz. the **sea-squirts** or **Ascidians.** These last are most wonderful forms. When young they lead an active life, swimming gaily in the sea, and in this stage of their existence they possess a notochord, a hollow brain, a tubular nerve-cord, and a pair of gill-slits. They soon, however, attach themselves to a rock and undergo rapid degeneration. The nerve-cord and notochord disappear, the brain becomes a small solid ganglion, but the single pair of gill-slits become enormously enlarged and converted into a trellis-work by the growth of partitions across them. The bars forming these partitions carry cilia, which serve to drive the water out which passes inwards by the mouth. The animal in fact converts itself into a vast filtering apparatus just as does a Sponge, only that the current is in the opposite direction. The Sea-squirt becomes enveloped in a gelatinous external skeleton, exuded by the skin and containing a substance akin to paper, and no one looking at a Sea-squirt adhering to a rock, and much resembling in outer appearance a Sponge, would imagine that it had any affinity whatever with a Vertebrate (Fig. 27).

The more normal Vertebrata which retain the backbone throughout life are divided, as we have seen, into Fishes, Amphibians, Reptiles, Birds, and Mammals. These five groups have, however, bonds which unite some of them more closely with one another than with the rest. Thus Fish are separated from the other four groups by the circumstance

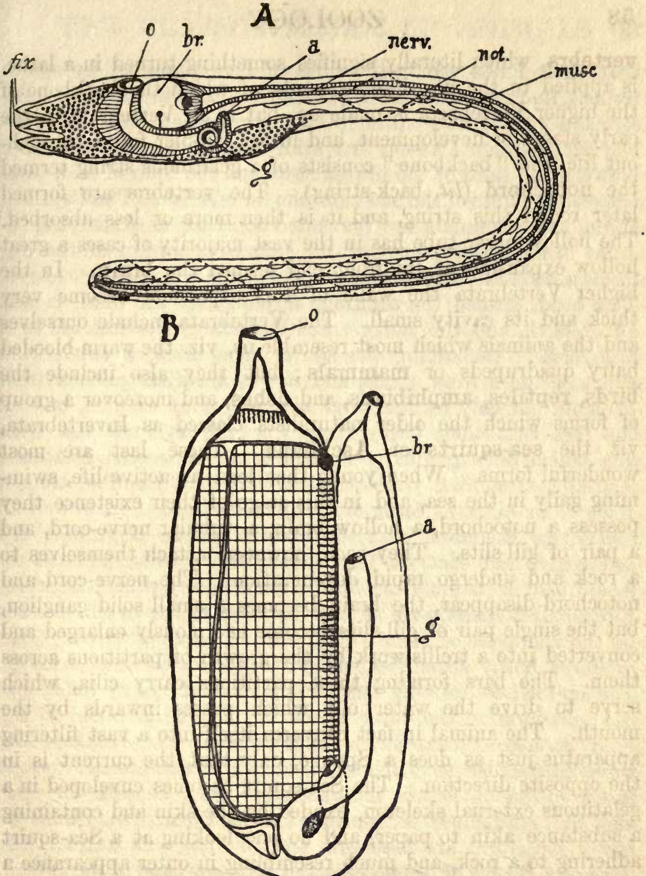

Fig. 27.—*A*, side view of Ascidian larva; *B*, side view of adult Ascidian cut open; *a* (in *A*), position of future anus; (in *B*), anus; *br* (in *A*), hollow brain vesicle; (in *B*), ganglion remnant of larval brain; *fix*, pagillæ by which the larva attaches itself; *g* (in *A*), single gill-pore on one side; (in *B*), trellis-work on side of the adult gullet which develops out of the gill-pore of larva; *m*, dotted lines indicating outlines of muscle cells which flank the tail on either side; *nerv.*, spinal cord of larva; *not.*, notochord or rudimentary backbone of larva.

that their limbs are in the form of fins supported by spines termed fin-rays, whereas the limbs of all the rest are constructed on the same principle as the human limb. As the late Sir William Dawson has said, there is more resemblance between the limb of the lowest newt and the limb of man than between the limb of the newt and the fin of a fish. The Reptiles, Birds, and Mammals are bracketed together as **Amniota**, because in the development of the embryo a portion of the egg forms a hood-like structure ensheathing the body of the embryo. This hood, termed the **amnion**, or popularly the **caul**, is cast off at birth, and the young animal enters on its free life in a form closely resembling the adult. Amphibia, a subdivision which includes frogs, toads, and newts, are distinguished from Amniota not only by the total absence of an amnion, but by the fact that they begin their free life as little fish with fins which only gradually change into four-footed creatures. Amphibia are often popularly confused with Reptilia, since a newt is in external form rather like a lizard. It is well to remember, therefore, that the skin of a true Reptile is dry and scaly, and that its toes terminate in nails, whereas an Amphibian is nailless and has a moist slimy skin. Reptiles, Birds, and Mammals are at once distinguished from one another by the character of their skins. In all three groups the skin produces horny structures which serve as a protection for it. The epithelium forming the skin is several layers thick, and the cells forming the outer layers dry up and give rise to the horny structures mentioned. In Reptiles these are **scales**—not to be confounded with the scales of fish, which are not formed in the epithelium but in the connective tissue beneath the skin, and the epithelium is continued over them. In Birds the horny structures are **feathers**, and in Mammals **hairs**. The wing of a Bird is of course only the arm and hand of the animal. In the hand only the thumb and two fingers are developed, and to the back of these fingers and to the forearm specially long feathers are attached which form a supporting membrane like the plane of an aeroplane. The Bat has also a wing which is formed from the hand, but in this case the supporting membrane of the wing consists of a web of skin stretched between the elongated fingers.

Of the enormous economic importance of the Vertebrata it is hardly necessary to speak. One has only to remember that our tables are supplied by fish, domestic poultry, and domestic mammalia, and that all other groups of the animal kingdom form an almost negligible source of food-supply compared to these. In tropical countries, Reptilia in the form of lizards and snakes are also consumed, and, as everyone knows, the epicures of the City of London consume the flesh of the marine turtle (another Reptile) at their banquets. Even Amphibia do not escape the attention of man; the limbs of the larger kinds of Frog are esteemed a delicacy in many countries—in Canada the large Bull-Frog is hunted almost to extinction.

In the earliest days of mankind the large carnivorous Mammalia were amongst man's most serious enemies, and even yet in tropical countries, among backward races of men, the lion and the tiger levy a large annual toll of victims. The poisonous snakes were another group of formidable enemies to mankind, and the dread of them is reflected in our mythologies. But where civilised man holds sway such enemies are rapidly overcome and entirely exterminated. The rate of reproduction of the higher Vertebrata is slow, and they are unable to recover from serious and continued losses. Thus hardly a decade passes that some kind of beast or bird does not become extinct; and however much the scientific zoologist may deplore this process, it is absolutely inevitable and must go on. Just as the Mammalia drove out the large Reptilia which preceded them, and whose colossal remains astonish the geologist, so Man is gradually exterminating all Mammalia and all birds, except those he finds a use for and those which are sufficiently inconspicuous to escape his attention. Only the fish of the sea with their enormous powers of reproduction seem to defy his efforts.

We have now passed in rapid review the most important divisions of the animal kingdom. Each primary division or phylum includes many different kinds of animals and is subdivided again and again. Thus phyla are divided into **classes**, classes into **orders**, orders into **tribes**, tribes into **families**, families into **genera**, and genera into **species**. The species is thus the unit of classification. It includes all animals, indistinguishable from one another by any constant mark (apart from the differences due to age and sex), which conjugate freely with one another and produce fertile offspring. When members of two different species are forcibly crossed with one another, in most cases no offspring at all are produced; in a few cases some young are produced which are themselves incapable of reproduction. Such young are termed **hybrids**; a familiar example of these is the *mule*, which is the result of a cross between the horse and the ass. In the very rare cases where the hybrids are capable of reproduction they exhibit an unstable heredity, and their offspring tend to revert to the father or mother species.

Whilst, so far as we know, the species is the same thing in whatever group of the animal kingdom it is found, this is not true of the higher divisions of the system. A genus of reptiles is a different thing from a genus of singing-birds. In fact all the higher denominations are merely names for more or less convenient bundles of species which resemble one another more or less closely, and the number of grades which we require in classifying a group of animals depends on the thoroughness of our analysis. It is often necessary to introduce intermediate grades of classification between order and tribe, family and genus, and so on; this is done by introducing the prefix **sub-**. Thus we speak of sub-genus, sub-order, &c., but these grades are only used if the species within a genus, for instance, fall into groups, the members of which more closely resemble one another than they do the other species belonging to the same genus; and often what one authority calls a sub-genus, another makes a genus, and so on. What the meaning of the system of classification may be, in a word, what is the **origin of species?** is one of the most profound and most interesting questions in zoology, and this we shall discuss in the next chapter.

CHAPTER VI

THE ORIGIN OF SPECIES.

We have just learnt in the last chapter that the species is the real basis of classification, and that higher grades of classification are only bundles of species. The question instantly occurs to one's mind, how did all these different species come into being? This may be said to be one of the two root-questions of biology; the other is, what is the chemical and physical nature of living substance?

To the question of the origin of species, Linnæus, who was first to define what was meant by the term, answered: "There are as many species as the Infinite Being in the beginning created." Now this answer is deserving of respect and careful examination. The object of all science is to determine the laws of Nature—that is to say, those constant modes of action which, as far as our experience goes, characterise all natural phenomena. Having determined these laws, it is the further task of science to calculate forward to what will be the cumulative result of these laws in the future, and to calculate back as to what has been the condition of affairs in the past. Now, as we have already seen, living things, whether plants or animals, originate only from pre-existing plants or animals, but if we interrogate the astronomer or the geologist as to the condition of the globe on which we live, he will inform us that it is a cooling body, and that at a certain period in past time it must have been a glowing white-hot body like our present sun. At such a temperature living matter could not have existed, since any living matter exposed to a temperature at all approaching this would be resolved into its ultimate elements. We are therefore led to the conclusion that life had a definite beginning on our globe, but as to how that beginning was caused Science cannot in the least help us. No process which we can study now will lead to the formation of living out of lifeless matter; and therefore it comes to much the same thing whether we say that living matter owed its origin to some natural process which does not now occur, and about which we know nothing, or that it owed its origin to supernatural process.

Now if life originated in some way which we can never know scientifically, there is no *a priori* reason why all the species of animals with which we are acquainted should not have originated at the same time. The chemist, until very recently at any rate, assumed that the eighty odd elements with which he was acquainted had existed from the beginning of time; and although he now knows that some of the heavier of these are undergoing a slow secular process of decomposition, which he can neither initiate or arrest, yet he is still left with a large number which by no known process can be changed into anything else. The remains of animals preserved in the rocks teach us, however, that many species which formerly existed on the earth have become extinct; and there is a general belief among geologists that none of the species now existing on the earth were living when the materials making up the first fossiliferous rocks were laid down as sand, mud, and gravel at the bottom of seas, lakes, and rivers. This belief is based on the experience that if we examine successively older and older rocks, the remains of existing species become scarcer and scarcer and finally disappear, whilst those of extinct species increase in number. This line of argument is, however, not conclusive, because although the *presence* of the remains of a species in a certain rock proves that the species lived at the time the rock was being formed, yet its absence does not prove that it was *not* then living. Only a small proportion of the species living at any one time were actually preserved as fossils; and of the fossils which actually exist, probably only a small proportion have yet been discovered. Every few years fossils of some type of animal are discovered at an horizon far lower than the lowest at which they had been previously supposed to exist.

There are, however, independent grounds for believing that the species of animals which we now find living have not been in existence since the beginning of life on the globe, but have arisen gradually as time went on through the operation of natural processes. These grounds are fully set forth in the immortal work entitled *The Origin of Species*, by Charles Darwin, a work which everyone interested in biology should read and re-read, and to which it is hoped that the present book may serve as an introduction. Darwin's work ought to be regarded as the Sacred Book of every student of zoology, for no work has done more to revolutionise the whole outlook of man on the universe than this one.

A very brief résumé of the principal lines of argument employed by Darwin may be given here. We find, Darwin says, that if a species be closely examined it is found to be divisible into different "races." These races are sections of the species consisting of slightly different types of individual confined to distinct areas within the single area to which the whole species is confined, and which is termed its **area of distribution.** The members of different races will interbreed freely with one another and produce fertile young; nevertheless, in some cases at any rate, the offspring tend to revert to the maternal and paternal types, and in this way we are reminded of the rare cases where two species will interbreed and produce fertile offspring. Further, in most cases he reminds us, we are in great ignorance as to whether two distinct types of animal or plant will or will not unite with each other so as to produce fertile offspring In few cases has the actual experiment been tried, and the vast majority of distinctions between species which closely resemble one another rest merely on the exhibition by all the individuals of each species of some constant mark or character which those forming the other species do not possess. So it comes about that what one good authority regards as merely distinct races another regards as distinct species. Now no one has ever suggested that all the different races into which each species is divided have existed since the beginning of life on this globe; they are universally admitted to have originated through changes produced in members of the mother species by the different conditions to which they have been subjected in different regions. The strong suspicion is therefore aroused that distinctions between species themselves are of the same nature as distinctions between races only carried to a further extent, *i.e.* that races are in fact only species in the making. This suspicion would rise to a certainty if we could show that there is on the one hand some natural process going on which tends to make the individuals of the same species differ from one another, and if we could further show that the property of sterility between two races when crossed could gradually appear. These are the two propositions which Darwin endeavoured to prove. He pointed out that no two members of the same brood of chickens, no two puppies of the same litter, were exactly alike, and that the differences between them were often inheritable. He asserted that breeders of domestic animals produced new "strains," *i.e.* new races of animals, by *selecting* from the litters of their stock those individuals which exhibited some particular trait which they wish to perpetuate. When such individuals were mated together, they often produced offspring in which the desired trait appeared in greater intensity; and by a continuance of such selective mating a race differing markedly from the parent race was produced. Thus, for instance, two breeders of sheep who had different ideals as to the type of sheep which they desired, produced in the course of years two flocks which differed markedly from one another, so that the veriest tyro could distinguish them. The origin of the principal breeds of domestic animal is lost in the mist of primeval history. In the case of the pigeon and of the dog they differ so much from one another that it has been often believed by breeders that they must have originated from distinct species; nevertheless Darwin showed by convincing argument that this cannot have been the case with the breeds of pigeon, but that they must all have arisen by the mating together of selected individuals belonging to one species. Thus he argued that the principal breeds, as for instance the pouter with its enormous crop, and the fantail with its colossal tail, exhibit features which are shown by no wild species of pigeon whatever. They differ from the wild rock-pigeon in characters sufficiently important to distinguish not merely species but genera from one another. Nevertheless they interbreed freely with the rock-pigeon, and have clearly been derived from that species. The question then arises, whether if man by "artificial selection" can create forms so different from one another as the fantail pigeon and the pouter pigeon, any process of **natural selection** exists which in course of time could cause the offspring of the same ancestor to differ as widely from each other as existing species do? That such a process does exist is the great point of Darwin's book. He lays stress on what we have already pointed out in this work, viz. that every species of animal tends to multiply itself so rapidly that it would soon overrun the globe unless it were checked, but that nevertheless the numbers of any wild species at present living do not vary much from year to year. This means that its numbers must be subject to constant depletion through the dangers to which they are exposed. Many individuals are devoured by enemies, many die from starvation during periods of scarcity, or from cold or heat during extremes of temperature, and the race will ultimately be propagated by those members which are **best fitted** to overcome and survive these troubles.

If external conditions remain the same, the species will remain fairly stable in its character; all the weaklings will be weeded out, and as time goes on an ever higher standard of fitness will be found amongst the survivors. But if conditions change for the whole species—or for a part of it which has wandered into a new environment—then a different standard of excellence will be required in the survivors, and a new race differing in character from the parent race will slowly come into being through the mating together of survivors possessing slightly different qualities from those called for by the old conditions. In this way as a species spreads it will slowly break up into daughter species, distributed over different regions of the globe, or distributed into different situations in the same region of the globe. These daughter species in course of time will come to differ from one another so much that they will be assigned to different genera, and by a continuance of this process the vast complexity of classes, orders, tribes, families, genera, and species within the limits of a phylum will come about. All the members of a phylum are descendants of a single species, but Darwin hesitated to assert that such different phyla as Arthropoda, Mollusca, and Vertebrata are descendants of a common type of ancestor. He rather inclined to the belief that if life apppeared on this globe by a process which we know nothing about, it may have appeared simultaneously in several different forms whose descendants remain as the different phyla to-day. It has been the task of succeeding zoologists to show that even phyla so distinct as Arthropoda and Mollusca afford evidence, when closely examined, of having been derived at some inconceivably remote epoch from common ancestors. But in order to complete Darwin's task it was necessary that he should show that the constitutional differences between species which express themselves in their inability to breed together are paralleled by minor differences of the same kind between breeds. This is a part of the work in which he was less successful than he was in demonstrating the existence of natural selection. But he showed that sterility can exist between different forms of the same species. Thus among plants there is the familiar example of the primrose, in which there are two forms of flower, one with tall stamens and a short pistil, and the other with short stamens and a tall pistil. If pollen be taken from the short stamens and placed on the short pistil, many vigorous seeds will be produced; and the same result will follow if pollen from long stamens be placed on a long pistil. But if pollen from short stamens be placed on a long pistil, or if pollen from long stamens be applied to a short pistil, then few and feeble seeds are produced: the result is therefore exactly the same as if two distinct species had been crossed. Darwin also showed that whereas in the majority of cases two distinct species were absolutely sterile when crossed with one another, yet this is by no means always the case; that in fact sterility is a question of degree, and that it is to be regarded as a concomitant of divergence of structure.

Darwin's teaching evoked the most violent opposition because it was in sharp contrast with previous views on the Universe, but amongst all the opponents of his views no one could gainsay the fact of the tremendous slaughter which goes on amongst wild animals; this fact was previously not denied, but conveniently ignored, and no doubt much irritation was caused by the manner in which this neglected fact was forced into the foreground of the controversy. The sole question at issue, then, is whether this slaughter subserves the welfare of the species or not, and most people will on reflection be inclined to welcome Darwin's view that it subserves a useful end.

It is obvious that Darwin's theory leaves entirely open the question of what causes those differences between individuals out of which natural selection gradually piles up the divergences of structure which separate species from species and genus from genus. These differences are summed up under the general title of **Variation.** In a later but less well-known work, entitled *The Variation of Animals and Plants under Domestication*, Darwin collected together all the evidence he could muster which could throw light on the origin of variations. This work is the grandest which he produced; to compile it was really the goal of his life, and the *Origin of Species* was intended by him to be merely a preliminary account of his work which the urgency of his friends forced him into writing, when it appeared probable that his ideas would be anticipated by another naturalist. Unfortunately the vogue of the "preliminary account" was so enormous that it completely overshadowed the full work of which it was meant to be the herald. The general conclusion at which Darwin arrived is that variations, so far as they are inheritable, are due to external conditions acting directly on the germ-cells, and that one external condition which seems to have had a great deal of influence has been the presence of an abundance of food. The efforts of biologists, both zoologists and botanists, since Darwin's time, have been in large measure directed to extending and confirming his work, and a great deal of research has been done with a view to finding out the nature and cause of variations. There is a popular idea abroad that one result of these researches has been to discredit Darwin's theory. It cannot be too strongly stated that such is not the case, and a brief statement of what has actually been accomplished will therefore be in place. At the same time that Darwin published his *Origin of Species*, Gregor Mendel, an Augustinian monk, was carrying on experiments in crossing different varieties of peas, and he arrived at a conception of the laws governing inheritance when two *races* of the same species were crossed, which has been called **Mendelism** and which has been largely confirmed by the work of subsequent workers. But these laws only apply to cases where the two races or varieties can be separated from one another by one or more clearly definable characters. Mendel himself expressly stated that he refused to have anything to do with differentiating characters which were of a "more or less" description. Now Darwin was well aware that amongst the domesticated animals such sharply-marked varieties—popularly known as "sports"—did occur, but for various weighty reasons he did not consider that they had been of importance in the building up of new species; the kind of variation which he believed has been "laid hold of by natural selection" was precisely that kind of "more or less" difference, *i.e.* slight differences in the proportion of parts of one animal as compared with those of another, which Mendel left out of account. If this view be correct, Mendel's views, while perfectly justified with regard to the subject-matter to which they were applied, have no relevance to the point at issue.

Mendel showed that the hybrid produced by crossing two well-marked races gives rise to offspring whose nature can best be accounted for by supposing that the hybrid produces two kinds of germ-cell of each sex in equal numbers, and that one type of germ-cell carries the differentiating character belonging to the paternal race, and the other type the character proper to the maternal race. When, however, two germ-cells carrying different characters unite in sexual union, the resultant offspring does not usually show a blend of the two characters, but one of the characters alone appears; this is termed the **dominant** character; whereas the other, whilst equally implanted in the constitution of the hybrid, does not affect its visible anatomy or appearance, and is therefore termed the **recessive** character. Of course this law finds its most obvious application in the character of the original hybrid produced by the first cross, which usually favours father or mother, but not both. The parent not represented in the visible structure of the child makes, however, its presence felt when that child comes to form germ-cells and produce offspring, for in some of the grandchildren the features of the "recessive" parent come forth again from obscurity. According to this discovery of Mendel's it results that when two races cross, the offspring of the hybrid gradually breaks up into the parental races again and the hybrids become relatively less numerous at each generation. Such a discovery, therefore, while it shows how two races occupying different but contiguous territories may keep distinct in spite of crossing, has no bearing whatever on the formation of new species. But the question now arises, what will happen when two races which differ from one another in *two* differentiating characters are crossed? The answer is that half the germ-cells of the first hybrid will contain one of each pair of differentiating characters and half will contain the other member of each pair, but that those germ-cells which contain one character of one pair are not in every case identical with those which contain one character of the other pair. It is exactly as if one had a number of balls in a bag and if one were to draw half of them out and paint them red, leaving half of them uncoloured, and if one were then to put the painted balls back again and shake the whole lot up together and then draw out half the number again and paint black dots on them. Half the number of balls would thus receive black dots and half would be without, but some of those which had black dots would be red and some would be uncoloured, and some of those which had no black dots would be red and some would be uncoloured. There would thus be four kinds of balls, viz.: (1) red with black dots, (2) red plain, (3) uncoloured with black dots, (4) uncoloured plain. Thus every time that members of two races distinguished from one another by two differentiating characters are crossed with one another, four kinds of germ-cells are produced; two of these varieties of germ-cell are the same as the germ-cells borne by the two parental races, but two carry new combinations of characters, and all these germ-cells if they unite with others of the same kind produce offspring with stable characters. Thus by crossing two such races two new stable varieties can be created. If two races are crossed which differ from one another in three definite characters, the hybrid produces six (*i.e.* 3 × 2) different types of germ-cells; if in four characters, eight (4 × 2) different kinds of germ-cells. It will thus be seen that by crossing two races differing in a large number of characters a very large number of new stable combinations can be formed. This discovery is of enormous practical importance, because it enables breeders to combine the desirable qualities found into different races and to produce a new stable variety bearing all the wished-for qualities. But there is grave reason to doubt whether any such process has played a part in the formation of natural species. Bateson, the most brilliant member of the Mendelian school, has shown that in most cases which are closely examined the differentiating character separating two races consists in the presence of one race of some substance or quality which is absent in the other race. The albino, or white mouse, for instance, is deficient in a substance necessary for the production of colour which the ordinary mouse possesses. Nearly all the differences between domestic races with which the Mendelian biologists have experimented are of this character. The wild race, or original type of the species from which the domestic race has been derived, is characterised by the possession of all the differentiating characters; the domestic race by the absence of one or more of them. All domestic races experimented with are therefore in a sense cripples, and their differences from the parent species of a different character from those which usually separate wild species from one another. The more enthusiastic followers of Mendel strive to prove that the only inheritable kind of variation—which they term a **mutation**—is of the kind produced from a new type of germ-cell which has arisen from such a new combination of inheritable characters as that alluded to above. Variations which consist in small differences in size and proportions are termed by them **fluctuations.** These fluctuations are due, according to them, to different conditions of nourishment acting on the same type of germ-cell, and such fluctuations are not inheritable. According to some of them, a natural species consists of a number of different races and each race is made up of individuals producing the same type of germ-cell. These races are termed **elementary species**; they are continually intercrossing and producing varied combinations, and it is, according to these writers, the variety of forms thus produced that has been mistaken by Darwin for continuous variability.

Now this view, if accepted, so far from helping us to understand the formation of natural species, brings us up in effect against a blank wall. How are we to account for the differences between the races or elementary species? how did they originate? To such questions the followers of Mendel have been able to give no answer. It is true that a leading botanist named de Vries, one of those who brought Mendel's work into full recognition, has put forward the view that natural species at intervals of time give rise to new "elementary species." The only instance of this, however, which he has been able to discover is open to grave suspicion. This is the case of an evening primrose which he found growing in Holland. But this plant is an introduced American form: it is strongly suspected of being a hybrid, and the supposed production of new varieties may be nothing more than the formation of new types of germ-cell with new combinations of the parental qualities such as we have just described in giving an account of Mendel's doctrine.

To sum up: the broad general considerations adduced by Darwin afford an overwhelming weight of evidence that new species have been and are being produced by the modification of old species; and the only theory which gives any probable account of how this can happen is his. Changed external conditions affecting the germ-cells and slightly affecting their hereditary potentialities—this is Darwin's account of the cause of variation, especially of that kind of variation out of which the differences between species have been built up; and no argument has yet been advanced to invalidate this view. It must be remembered, however, that the experimental proof of this view would require a period of time greatly exceeding the span of a single human life, whereas the number of types of germ-cells produced by a hybrid is a matter which can be determined by experiments lasting only a few years. The evidence in favour of Darwin's view must therefore for a long time remain indirect; but whoever will take the trouble to compare the small wild horse of Northern Europe and Asia—pictures of which were scratched by primitive man on flint and specimens of which can be seen in the London Zoological Gardens, with the noble dray-horses which drag heavy loads in the London streets, will form some conception of what may be accomplished in thousands of years by steadily mating together the strongest and best of a species.

CHAPTER VII

THE CONSEQUENCES OF DARWIN'S THEORY. THE INTERPRETATION OF DEVELOPMENT.

In the preceding chapter we have given a brief sketch of Darwin's theory of evolution and of the reasons for believing it to be true. We have now to examine some of the consequences which must follow if the theory be accepted. The first of these consequences is that greater or less likeness between two species of animals is *prima facie* evidence of nearer or more distant blood relationship, and that the proper classification of animals is one which most adequately expresses this relationship. But animals in their growth from the germ until they reach the adult condition pass through a great number of stages in which they may present quite different appearances, and the study of these stages is termed **Embryology.** The most familiar example of this is found in the life-history of the frog. As every one knows, the frog when young lives in water and strongly resembles a fish, and is then known as a tadpole. If the tadpole be carefully examined it will be found to present strong resemblances in structure to an archaic type of fish known as the lung-fish, and represented now only by three types, one confined to the rivers of Australia, one to the rivers of Central Africa, and one to the rivers of South America. Like the tadpoles these fish possess both lungs and gills, and in the arrangement of their blood-vessels and in the structure of their brains there is likewise a strong resemblance to tadpoles. If we interpret these resemblances as evidence of blood-affinity we shall be bound to conclude that frogs have been developed out of lung-fish. Now it happens that there is corroborative evidence from fossils to support this conclusion. In the rocks known as Devonian or Old Red Sandstone there are numerous remains of fish. Many of these, according to the opinion of the best experts, were allied to the lung-fish. In the Carboniferous rocks which lie above the Devonian, in which the coal-seams are found, abundant remains of very primitive frog-like and newt-like creatures have been discovered, and there seems to be a strong probability that frogs and newts, that is, Amphibia, were evolved out of creatures like lung-fish in the interval between the periods represented by these two sets of rocks. But if this conclusion be accepted the consequence follows that the frog, in its growth from the egg to the adult condition, gives a summary of the history of the race of frogs in their age-long progress from the condition of fish to the condition of land animals. Now this case of the tadpole and the frog is only one of numerous instances of the same sort of thing. Thus, for instance, the oyster is an exception among bivalves, in that it possesses no foot—*i.e.* no axe-like median muscular mass attached to the underside of its body. But the American oyster, when about $\frac{1}{8}$-inch long, has such a foot, which it loses as it grows up. When young it moves about, but when older it stays in one place. There are small salt-water shrimps belonging to the class Crustacea, which when young swim about freely and resemble other species of the same order, but which when older attach themselves to the gills and mouth of fish and degenerate into shapeless parasites whom no one would suspect of belonging to the class Crustacea if their younger stages were unknown. No naturalist has any doubt that these parasites are the descendants of forms which once swam freely about like other Crustacea, and if so, then undoubtedly they recapitulate in their development the history of the race.

We might add to the list indefinitely, but one other example must suffice. The beautiful feather-star, one of our less-known Echinodermata, which can be dredged in shallow water all round our coasts, possesses when adult a mere blunt knob in the middle of the back from which rooting processes originate; it can hold on for a time to a given spot by these processes, and it can also let go and swim about by movements of its delicate arms until it finds a more suitable place. When young, however, the feather-star has a delicate stalk springing from the middle of the back, and by this stalk it is permanently anchored to one spot. Now the Carboniferous limestone in some parts of England is in large measure made up of the broken fragments of the stalks of extinct feather-stars, and it is practically certain that amongst these ancient stalked feather-stars the ancestors of our present feather-stars are to be found. Here again the life-history of the individual recapitulates that of the race. Since this principle is found to hold where we have independent evidence as to what the ancestry of a given form has been, it seems justifiable to conclude that it underlies the development of an animal from the egg in all cases, since it seems a reasonable supposition to hold that this development is the same sort of thing wherever it occurs. Hence Haeckel formulated what he called "**The fundamental law of biogenesis**" in the words which we have just used, viz.: "The individual in its development recapitulates the history of the race." When once the idea was grasped that life-history in general had this meaning, an immensely increased interest was awakened in its study and elucidation, and this interest has lasted in scarcely diminished degree till the present day. The field of research is certainly limitless; there are at least one million distinct species of animals living at the present day, each with its distinct type of life-history—in few cases is the complete life-history known, in a good many more cases only bits and scraps of this history have been made out, but in the vast majority of cases nothing at all of it is known. The recapitulatory interpretation of life-history was pursued with such fervour during the latter half of last century that it provoked a reaction, and many naturalists now speak slightingly of this theory. The fact is that although recapitulation is the main factor in determining the course of a development, other factors have co-operated in producing the result, so that, as the late Professor Balfour said, the life-history is like an old damaged record with pages missed out, with other pages blurred, and with intercalation of false matter. How does the historian proceed when he tries to decipher such a document? He compares it carefully with all the other documents of the same age which he can obtain, and the true is separated from the false by the consistency of the one and the inconsistency of the other. So the recapitulatory interpretation of life-history must be based on *Comparative* Embryology, *i.e.* a large number of life-histories must be deciphered and compared with one another before the recapitulatory interpretation can be applied with any confidence. But this is a slow process, and the ardent young naturalist who deciphers a new life-history is usually burning with impatience to apply the recapitulatory theory to it at once. Hence we can easily understand that most contradictory results have been obtained from the applications of this theory, and hence the reaction against it. The line of research most in favour at present is termed **Developmental Mechanics** or **Experimental Embryology.** The object of this study is to explain the developmental processes which go on in an egg, on the basis of its own structure, without calling in the aid of the recapitulatory theory at all. The experimenter cuts off parts of the egg under observation or displaces the mutual relations of the parts by pressure, &c., and then observes the result. In this way he hopes to find out what are the potencies of the various parts of the egg and how these parts influence each other. But the progress of this research has only brought out the fact that no form of egg is capable of explanation by reference to its own structure alone. We find that eggs differ widely from one another in their constitution. In some cases, as in Worms and Molluscs, if a portion of the egg be cut off the creature which develops from it will have some important part of its anatomy missing. In other cases, as in some Echinodermata, the egg can be cut into eight pieces and each piece if it lives will develop into a creature just like the normal form, only of proportionately reduced size. Why the eggs of one form are constituted in one way, and those of another in another way can only be explained on the principle of heredity; on the ground of the affinities of the parent form and its position in the animal kingdom.

Developmental Mechanics is in fact an adjunct and not a rival to Comparative Embryology. By its means we analyse an egg into its essential factors far better than we could by looking at it through the microscope or even by cutting a thin section of it. But no developmental mechanics will enable us to explain why the feather-star loses its stalk, or the young oyster its foot; to give any rational account of such occurrences we require the recapitulatory theory. If then recapitulation of ancestral history should be the main factor in determining development the question arises, what are the other factors which modify it? The elucidation of the secondary factors is an inquiry on which comparatively little work has been done and on which, it is to be feared, no very clear conceptions exist in the minds of many naturalists. A few of the more obvious may be briefly alluded to here. The young of animals exist under two phases, termed respectively the **larval** and the **embryonic**. In practically all life-histories both phases occur: the life-history starts by being embryonic and becomes larval before the adult stage is reached. In the larval phase the young animal moves actively about and seeks its own food; in the embryonic phase, on the contrary, it is supplied with food either in the form of yolk-grains embedded in its tissues or in the form of secretions from the maternal womb; and it lives a sheltered life either within an egg-shell or within the womb. All the clearest and most striking evidences for recapitulation occur in the larval phase: and we have every right to assume that the larval type of development is primary and that the embryonic phase is a secondary modification of it The digestive tube of a larva must be in full functional activity, ready to receive and digest food; but that of an embryo may be, and often is, a solid string or mass of cells packed with yolk. The limbs of a larva must be functional—those of an embryo are often functionless stumps. Then again in both phases of life-history, but most markedly in the embryonic, we find a tendency towards the **dislocation of development**, by which phrase is meant the precocious development of organs which are of importance to the adult, so that the body of an embryo at one time may represent two periods of ancestral history at the same time, each affecting a different group of organs. This indeed seems to be one of the most frequent factors in modifying development. Lastly, the circumstances of the larva may undergo secondary changes whilst those of the adult remain relatively the same: in this case special larval modifications may arise which may obscure the ancestral type; thus in the majority of cases insect-larvae live in very special surroundings to which they are specially adapted.

If we then accept the theory of recapitulation as having the great balance of probability in its favour, we may now reflect on what this theory implies as to the course which has been pursued by evolution. According to this theory a larva primarily represents an ancestral stage in the history of the species, and the larval circumstances are a picture of the ancestral environment. When the larva changes into the adult, or to use the technical term, **metamorphoses**, it deserts the ancestral or larval environment and enters into the modern and adult one. We seem therefore driven to conclude that in past time a new species was made out of an old one by the **migration of some of its members** into a new environment and their consequent exposure to new influences amongst which the most potent may have been a new kind of food. Now in Chapter II it has been pointed out that every species tends to reproduce itself at such a rate that if unchecked it would soon overrun the world: it was indeed compared to a fire in a dry prairie, which is always striving to spread at its borders. This comparison appears to be increasingly justified the more the circumstances of the life of species is looked into. It has been shown that for many species there is a mother country, in other words, a suitable environment where each flourishes and multiplies so that in this country it is swarming. The surplus population spreads outwards from the borders of the country seeking room. In most cases, alas! the colonists perish, but once in a long while they manage to establish themselves and thus a new race comes into being. The incursion into new territory seems to occur in the majority of cases in the adolescent stage; the younger stages of growth being passed through in the mother country: these younger stages then constitute a **larval phase.** Now in response to the new environment the structure of the latest stages becomes altered—and that adult structure is capable of alteration under the stress of new circumstances is a well-known fact—but we are bound to assume that this change of structure has in time become transferred from the body **(soma)** to the germ-cells, so that these now have acquired the tendency to develop the new type of structure at earlier and earlier periods in the life-history and quite independently of the stimulus of the new environment. Thus the recapitulatory theory, which is an inevitable deduction from the general theory of evolution, is calculated to throw in turn considerable light on the nature and origin of inheritable variation. The tendency of the Mendelian school to regard the properties of the germ-cells as being as unalterable as those of the chemical atoms is certainly in direct contradiction to the impression gained by a comprehensive survey of the life-histories of animals.

If we use the weapon which the recapitulatory interpretation of enbryology puts in our hands, and explore what the actual course of evolution within the great phyla has been, we seem to see that in each phylum Nature has striven after the elaboration of some organ or group of organs which have been dominating factors in the life of members of the phylum. To take the most familiar instances: amongst carnivorous mammals the teeth and claws are the all-important things, and so we find in tigers the great eye-teeth enlarged into formidable spears, whilst the back teeth are reduced to one or two pairs of powerful scissors; the claws are bent back when not in use so that their points may not be worn down, and the animal walks on the hairy second joints of its fingers and toes (the well-known "furry" paw of the cat). Various kinds of cat-like animals are classified by the degree of perfection attained by teeth and claws.

Amongst hoofed animals or **Ungulata** the teeth, hoofs, and horns are likewise the dominating features of development. The teeth, with the cunning alternations of harder and softer material on their elaborate grinding surfaces, are indispensable implements in grinding into impalpable powder the hard and gritty food on which the Ungulata live; the hoofs are arrangements to permit of long-continued running, and the horns are the final defence of the animal against attack. The perfection of these three sets of organs varies from group to group, and hence they are made the basis of classification. This list could be extended indefinitely. In bivalve mollusca the gill, clothed with ciliated epithelium which wafts the food-bearing current of water to the mouth, and the prolongation of the mantle termed the **siphon** (see Fig. 20), which enables the animal, though buried in mud, to maintain connection with the vital air-containing sea water above, are the dominating organs, and classification is based on them. Among insects the modified limbs round the mouth termed "jaws," or gnathites by the aid of which they obtain and masticate their food, and the wings which bear them from place to place are the basis of classification.

If the question be put, how can any but the most perfected organisations survive until the present day? the answer is twofold. First, competition and natural selection are not equally severe in all areas. In small secluded areas less perfect forms of life may survive for millions of years after their congeners have been eliminated everywhere else on the globe. Thus in New Zealand the Tuatara, a primitive form of reptile, still survives: its nearest allies swarmed all over Europe, Asia, and Africa in the Triassic period. Again, all perfection in an organ implies specialisation in function; and the power of carrying out one function in perfection implies more or less the giving up of the power of using the perfected organ for any other purpose. Less perfection in structure may be compensated for by greater power of adaptability to various uses as the life of the animal may demand.

The paw of the dog is a much less perfect instrument than the paw of the cat for striking prey, but the paw of the dog can be used for long-continued running, whereas the cat is only capable of a few short dashes at a time. The wild congener of the dog, the wolf, can run down and tire out his prey, but the lion or tiger must surprise its prey and seize it with a sudden spring; such animals are incapable of catching it by a straightforward pursuit.

The study, however, of the relations of animals to their environment and to each other constitutes the lifelong fascination of the study of Zoology: it is indeed like a great book of fairy-stories, wherein every new page contains fresh surprises —the probing into it affords a constant source of pleasure which, as Sir Ray Lankester says, persists when all other pleasures seem vain.

Before, however, we can enjoy this pleasure or appreciate the marvels which Nature spreads before the discerning eye, we must attain a fair knowledge of the main types of structure met with in the animal kingdom, and this knowledge it is of course utterly impossible to impart within the limits of a book like this. It is not to be attained, and therein it resembles all valuable things, without a certain amount of drudgery; we must begin *by knowing*—before we can compare. All scientific zoology must be based on the detailed study of types. To this study of types, each considered as an isolated problem, Huxley gave the name *Biology*, and on this subject he wrote his *Elementary Biology*, the first text-book in which the anatomy of certain types was carefully described. Many good text-books on the subject have been written since, and a list of the most suitable will be found in the Appendix.

CHAPTER VIII

THE BEARING OF ZOOLOGY ON THE QUESTIONS OF HUMAN ORIGIN AND THE FUTURE DESTINY OF THE RACE.

In the last chapter we were occupied in discussing the relationships of animals to one another, and the light which has been thrown on these relationships by the work of Darwin. Interesting as it is to unravel the relationship of one group of animals to another group, it is not half so interesting as to determine the relationships and history of the human race. The bearing of the doctrine of evolution, therefore, on the origin and future of the human race has always been a topic of absorbing interest. The most superficial examination will convince us that our bodies are constructed on the same general plan as those of all other Vertebrata, and that all the arguments used in favour of the blood-relationship of various groups of Vertebrata with one another, apply equally strongly in favour of the kinship of the human race with the higher Vertebrata. We are typical Mammalia with a covering of hair protecting our skins, a four-chambered heart and an apparatus of sweat glands to regulate our temperature, and the division of the Mammalia to which we show most resemblance and with which we should undoubtedly be classed by an intelligent visitor from Mars is the order of the **Primates** or Monkeys. In fact, at the present day it may be confidently asserted that there is no intelligent naturalist who is not convinced that the human race is descended from monkey-like ancestors; and the quibbling objection which is sometimes raised, that our ancestors could not have been identical with any race of monkeys existing now, is entirely beside the point. Our ancestors *may* have so closely resembled a race of monkeys still living that they would have been included in the same species. Yet it would in nowise follow that human beings should in that case be in process of evolution now; for, as we have seen, a new species arises out of an old one through spreading into a new environment: now the environment into which an incipient new race of men would spread is fully occupied by the present human race, and there is thus no room for the development of any other race of man-like creatures from living monkeys.

When we come to examine where the environments of monkeys and men differ, we find that much light is thrown on the factors which led to the development of mankind. Monkeys are tree-loving animals; without exception the lives of all species are passed in climbing from branch to branch, and their descents to ground are quite exceptional, and this applies equally to those monkeys like the Gorilla and Chimpanzee, which most closely resemble man, as to those lower races like the Spider-monkeys and Marmosets of Brazil, which least resemble the human species. The human race, in contrast with the monkeys, are **Ground-Apes** which have deserted the trees and taken to the open country for their means of subsistence. It follows that once they had successfully adapted themselves to new conditions they were enabled to spread all over the globe, while their backward cousins whom they left in the forests are doomed to undergo diminution in numbers and final extinction as the forests disappear. But there is no serious question that forests have been gradually disappearing for millions of years, and with the attainment of the weapons of civilisation by the human race their disappearance has been hastened. The reason for the prehistoric disappearance of forests has been the evolution and spread of hoofed animals. The hoofed animals gradually destroy forests by tearing out and eating the seedlings of the trees, and every great stretch of natural open country is related to the existence of one or more wide-ranging species of hoofed animals. Thus, to take one example, the prairies and the bison of North America were not disconnected phenomena: the bison was the cause of the existence of the prairies. Now the evolution of hoofed animals seems to have reached a climax towards the end of the warm Miocene period, which was succeeded by the period of snow and icefields extending to the middle of France which is known as the Glacial period. It is a geological and not a zoological question as to what was the cause of the mild period and of the succeeding icy one; but when we find evidence from the remains of plants in shale that during the warm period the magnolia flowered in Greenland, and when we find that later our own hills were covered with snow and our valleys occupied with glaciers, we have no doubt of the *facts*, and these are all that we require for our purpose. When, therefore, herds of wild oxen and deer roamed over grassy plains occupying the site of our islands—plains that were then continuous with the great plain of Northern Europe—the forests must have become more and more restricted, and somewhere in the northern continent—it is impossible to say where—an enterprising race of monkeys began to seek its livelihood on the ground, and so the human race was born. The species of monkeys living at present are pre-eminently fruit-eaters, but some of the more active, like the Gibbon, do hunt down and catch the smaller mammals and birds, and thus enjoy a mixed diet. The first traces of man's presence on earth consist in simple tools made of sharpened stones and of charred fragments of bones of the larger hoofed animals, which indubitably prove him to have been a hunter. But how could a climbing animal whose natural food was nuts ever become a match for the powerful and fleet Ungulata? If we examine the anatomical differences between ourselves and the highest monkeys, we find that they consist mainly in two features: (1) the feet and legs are converted into pillars capable of supporting the body without aid from the arms, and (2) the brain has become greatly enlarged. The first change converted a climbing into a running animal; hints of this change are seen in the behaviour of the Gibbon to-day. This animal alone among monkeys is able to run on the ground without aid from its arms, and, as we have seen, it hunts down small animals, for which purpose Gibbons associate together in herds. Now here we have the essence of the evolution of man. To hunt down large and powerful animals it was necessary that primitive man should associate in bands—and it was also necessary that he should be able to run swiftly. As an isolated animal, man was no match for his fierce and powerful competitors. His strength was as nothing to that of the woolly elephant or the wild ox, to say nothing of the cave-bear or cave-lion; only when acting together in a **tribe** was he able to maintain himself. The evolution of man is therefore the evolution of **society**.

From the few scraps of human bones which have been recovered from pre-glacial and mid-glacial days, we seem to be warranted in concluding that the erect posture had been attained and the consequent modification of the foot and leg had been accomplished long before glacial times. Some of the oldest skulls, however, show in their projecting brows and flat brain-cases unmistakable resemblances to those of the apes. One fragment named *Pithecanthropus*—literally, "Ape-man"—found in Java, seems to indicate a size of brain exactly intermediate between that of the highest ape and that of the lowest men living to-day. The brain, like every other organ of the body, grows in proportion to the demands made upon it; in a word, with the evolution of society. The brain seems to have attained its present size before the end of the glacial period; at least the brains of the extinct race called Neanderthal man have now been proved to have been as large as those of modern Europeans. The shape of the brain-case of Neanderthal man, however, indicates that the same parts of the brain were not so highly developed as in modern man; it seems as if the part of the brain devoted to motor activity, *i.e.* the part which gave out the impulses to the powerful limb-muscles, was more developed than the part concerned with reflective thinking. Now the purpose of society is to perform common actions for the general good; and the whole of human history since the glacial epoch has consisted in the development of this co-operative spirit. Necessary actions in the lower animals are secured by appropriate instincts: thus a cat when attacking prey strikes it with the fore-paw, whereas a dog seizes it with his jaws. *The upholding of the co-operative spirit in man is in similar manner maintained by his moral instincts—i.e.* his feeling that he *ought* to do certain things regardless of consequences. The main things which morality ensures are that man shall uphold his tribal brother and that he shall be loyal to his leader. This latter quality is just as important as the former; a tribe without loyalty to its leader, like the army imagined by a modern dramatist, "Where the soldier would be man enough to strike his officer in the face" when he gave an order, would have been speedily removed by natural selection.

The struggle for existence, then, was not between individual men as such, but between tribes, and this is where philosophers like Nietsche who talk of the "superman" appear to us to go so far astray. They picture the struggle for existence as a struggle between individuals; they imagine mankind as progressing by the appearance of "supermen" of great size, strength, intelligence, and ruthlessness, who will pursue their own ends regardless of their weaker brethren. Such a view is radically false. Mankind progresses by the appearance of individuals in whom the instincts of co-operation and loyalty are more strongly developed. Originally, no doubt, the tribes kept each to their own hunting-grounds just as packs of wolves do now, but as mankind wandered into new areas and got broken up by different vicissitudes into races or incipient species, then some of these races would multiply beyond the resources of their food-supply and would invade the territory of another tribe, and so inter-tribal warfare would begin. Just such a history has been experienced on a small scale in the island of Tasmania. This island when discovered by Europeans was inhabited by a primitive race of men, who used the same tools as did the inhabitants of Great Britain in mid-glacial times. They seem to have lived on fairly good terms with one another, and inter-tribal wars were rare. But when the coast was occupied by Europeans for sheep-farming, the natives who had lived there were displaced; they invaded the grounds of the tribes who lived in the interior, and a period of internecine warfare ensued, with the result that in fifty years the population was exterminated. There is evidence to show that in mid-glacial times England and Europe were inhabited by a race akin to the Bushmen; these were displaced by tribes with higher culture, and only a small perishing remnant of this race survives to-day in South Africa. Still later, when the ice age was passing away, our caves were the retreat of a race akin to the Esquimaux. A few thousands of this race survive in the farthest North; they are fast disappearing as they come in contact with higher races. They are mercilessly slaughtered by Red Indians, and Europeans unwittingly contribute to their destruction by the diseases which they spread.

As the essence of morality consists in co-operation and loyalty, so the essence of reason and intelligence is the adaptation of new means to ends; it is this which as frequently as superior tribal virtue has given the victory to one tribe over another. It is the opinion of some most competent authorities that the victory of what are called the Neolithic peoples—of those who had the art of making axes of polished stone—over the peoples living in Europe at the close of the glacial age, was due to the Neolithic discovery of the art of tying a stone knife to a wooden handle and thus making an axe of it. It was the mastery of the horse that enabled the Semitic populations of the East to overrun all Northern Africa and Southern Europe, and to replace the Cross by the Crescent. On the other hand, the Roman Empire was founded not on superiority of knowledge or of inventive capacity on the part of the conquerors, but on superior discipline—that is, on tribal loyalty.

If, then, the essential feature in human history has been the victory of one tribe over another, and if this victory has been mainly dependent on two factors—tribal morality and inventive capacity—it becomes a vital question to us all to see how far these necessary factors are embodied in our own tribe, and what consequently is the outlook for its continued success.

We have seen that the two elements in tribal morality are faithfulness to the tribesmen and loyalty to the leader. But these virtues demand for their healthy development that the tribesmen and leader should know and trust each other. As all are aware, however, for the last eight thousand years there has been a constant tendency to amalgamate tribes into larger wholes, and so to form kingdoms and empires. The mutual knowledge demanded for tribal loyalty tends to be diluted in this process, and so the tie of affection is correspondingly weakened. Many such combinations have resisted the disintegrating forces for a time and then gone down before the assault of tribes in whom the tribal loyalty was strong and vigorous. Thus did the Roman Empire fall before the attacks of Northern tribes; and the feudal system which succeeded it is only tribalism under another name.

The British army is founded on the tribal spirit. It is called the regimental spirit; but that is only another name for the same thing. The regiment primarily—not the fatherland—is what the soldier lives and dies for. But the army forms only a small proportion of the millions who make up the amalgamation known as the British Empire, and the danger of putting power in the hands of thousands who render no corresponding service for the privilege is one which is constantly overlooked by politicians—but it is a mistake which will one day have to be paid for.

The difficulty is to combine the intense loyalty shown by the members of a regiment to one another with the enormous extent of modern kingdoms. This difficulty was in former days overcome by religion. The biological function of religion has always been to uphold the sense of duty, without which the tribe perishes. The original form of religious belief is the continual spiritual presence of a dead leader who watches over the tribe, to whom all must be loyal. Primitive Christianity was a belief of this kind, and on it our modern civilisation is built. In modern times, however, it is doubtful how far beliefs of this kind can fulfil their original function. Their driving force is continually being weakened by scientific teaching, and unless we should acquire a leader who should re-state in modern language the essential parts of old teaching so as to bind the nation together in a new unity, not much is to be hpoed for from that quarter.

If, then, our condition is far from satisfactory on the side of loyalty, let us look at it from the point of view of adaptation and invention. Are we superior to others in adaptation of means to ends? There is no question that we *were* superior. But superiority is a relative term. A superiority based on rule of thumb, on the following out of rules gained by hard experience, is an excellent thing so long as no one finds out a better way of accomplishing our tasks. But a superiority based on the systematic encouragement of scientific research and the immediate appropriation of its latest results is a far better thing, and this is the method adopted by Germany and Japan. This method, it seems to us, is bound to win in the long run, just as surely as the Neolithic axe prevailed over the ancient chipped flint-knife, or as the bronze weapon in turn conquered the axe.

There are, however, still other considerations to be weighed. A species of animals living under natural conditions is kept in a state of health and vigour by natural selection. All weak and diseased specimens are ruthlessly eliminated, and only the strong and active reproduce their kind. Under modern conditions of civilisation, the effort is made to preserve all, however diseased and imperfect, alive, and to oppose no check to their reproduction. The practical result of this is, that the most reckless and criminal members of society reproduce early and often, and impose the burden of the care of a worthless progeny on the thrifty members of society, who in consequence limit their own reproduction. From whatever point of view this state of affairs is viewed it must cause apprehension. In the so-called good old days, when plagues and wars periodically wiped out large numbers of the population, only the most vigorous survived, and the quality of the race was not impaired. If we go still further back to the palmy days of the warlike tribes who founded the city-states of Greece and Rome, we learn that sick and weakly infants were not allowed to live.

In fact it may be broadly stated that in all primitive tribes which occupy a limited area, care is taken not to have more babies than are required.

It is not seriously suggested that infanticide should be practised in a modern Christian state; only that means should be taken to render it difficult or impossible for the unfit to breed. A beginning has been made by Eugenic societies in stirring up public opinion on the subject; *but no way could be devised in which public opinion could be more effectively stirred up than by making a fair knowledge of zoology a necessary element in modern education.*

The lessons which the Eugenist seeks to enforce are written in flame across every page of zoology: the wiping out of less perfectly developed and less adaptive tribes by better equipped ones is going on daily under our very eyes. If this sort of mental pabulum were supplied to those who are likely to become our public men and leaders instead of the exclusively classical education on which the last generation has been reared, the Eugenist would not preach to deaf ears, and there is at least a chance that social and economic questions would be fairly faced instead of being merely tinkered with. It is easy to put from one's mind general talk about natural selection if one has had a non-scientific education, for the term probably does not convey a definite image to the mind, but to the man with even a very moderate zoological training it means something infinitely too important to be put on one side. Let us hope that a time is coming when a knowledge of the laws of life will be thought to be at least as important as acquaintance with the rules of the grammar of dead languages.

It would be futile to close a book like this without some reference to the objection that zoology deals with man, as if he were body without soul. The answer to this objection is twofold. First, zoology, as a natural science which deals with phenomena perceptible by the senses, must deal with man as it deals with other animals, as if they were bodies only. Whether man's behaviour is entirely explicable as the outcome of the chemical energy of his body is a question which lies entirely outside the province of zoology. Secondly, all that zoology asserts concerning man is not that he is merely body, but that he and the animals are akin. It may be that in the behaviour of the higher animals there are elements also which are not explicable on any purely materialistic theory, but if this be so the best way to define them will be to push materialistic explanation as far as ever it will go, so that its limits will be clearly seen. Whether the non-material element in man can survive the body or not is a question of enormous interest, but one to which, naturally, zoology can give no answer; but if ever a satisfactory answer to it be found, it will only be as the result of the same kind of slow, patient, persevering research as that by which the natural sciences have been built up—such research as, amid much discouragement, is being undertaken by Sir Oliver Lodge and his friends. In the meantime, however, the doctrine of evolution with its consequence, the kinship of man and animals, can throw welcome light on some old moral problems. One of these is the nature and origin of evil. Evil in man may be briefly defined as want of self-control and want of subordination to law, *i.e.* to tribal morality. Now the organ of self-control is the brain, especially the frontal portion of it. This part has been slowly developed through thousands of years by natural selection. Savage tribes—who are the last remnants of primitive types of man—have less self-control than civilised man. Tribal morality or subordination to law is also a quality which has been slowly and painfully evolved. Now in other types of animals in which an important organ has been the dominating factor in evolution, we find that races are sometimes developed in which this organ is degenerate. At every step of the upward progress some step back. Thus we find wingless insects, toothless quadrupeds, &c. *Evil is therefore the reversion to a previous state of evolution,* and the so-called original wickedness in children is a repetition of an ancestral stage of the race—as truly a larval stage as the tadpole stage of the frog.

Huxley has compared Life to a game of chess in which all must take part, but in which the Player of the other side is hidden from us. This Player, he says, never forgives offences, but exacts the full penalty for each. The final and deepest object of zoological science is to learn some, at least, of the rules of the game.

APPENDIX

List of Books recommended for the further Study of Zoology to the Readers of this Book

The works of Darwin are alluded to in the text. This list is arranged in order of complexity, beginning with the most elementary text-books.

Lesson in Elementary Biology.—T. Jeffrey Parker.
A Junior Course of Practical Zoology.—A. Milnes Marshall and C. Herbert Hurst.
The Frog: An Introduction to Anatomy, Histology, and Embryology.—A. Milnes Marshall.
An Introduction to the Study of the Comparative Anatomy of Animals.—G. C. Bourne.
Text-Book of Zoology.—J. Arthur Thomson.
Text-Book of Zoology.—A. E. Shipley and E. W. MacBride.
Vertebrate Embryology.—A. Milnes Marshall.
Students' Text-Book of Zoology.—A. Sedgwick.
Text-Book of Comparative Embryology. Vol. I, "Invertebrata and Protochordata" (in the press).—E. W. MacBride.
The Cambridge Natural History, Vols. I–X.

INDEX

Printed by BALLANTYNE, HANSON & Co.
Edinburgh & London

THE PEOPLE'S BOOKS

THE FIRST HUNDRED VOLUMES

The volumes issued (Spring 1913) are marked with an asterisk

PHILOSOPHY AND RELIGION—(*continued*)

*74. The Free Churches . . . . By Rev. Edward Shillito, M.A.
75. Judaism . . . . By Ephraim Levine, B.A.
*76. Theosophy . . . . . . By Annie Besant.

HISTORY

*36. The Growth of Freedom . . . By H. W. Nevinson.
37. Bismarck . . . . By Prof. F. M. Powicke, M.A.
*38. Oliver Cromwell . . . . . By Hilda Johnstone, M.A.
*39. Mary Queen of Scots . . . . By E. O'Neill, M.A.
*40. Cecil Rhodes . . . . . . By Ian Colvin.
*41. Julius Cæsar . . . . . . By Hilary Hardinge.
History of England—
42. England in the Making . . . By Prof. F. J. C. Hearnshaw, LL.I
*43. England in the Middle Ages . . By E. O'Neill, M.A.
44. The Monarchy and the People . . By W. T. Waugh, M.A.
45. The Industrial Revolution . . . By A. Jones, M.A.
46. Empire and Democracy . . . By G. S. Veitch, M.A.
*61. Home Rule . . . . . . By L. G. Redmond Howard.
77. Nelson . . . . By H. W. Wilson.
*78. Wellington and Waterloo . . . By Major G. W. Redway.
100. A History of Greece . . . . By E. Fearenside, B.A.
101. Luther and the Reformation . . By L. D. Agate, M.A.
102. The Discovery of the New World . By F. B. Kirkman, B.A
*103. Turkey and the Eastern Question . By John Macdonald.
104. A History of Architecture . . . By Mrs. Arthur Bell.

SOCIAL AND ECONOMIC

*47. Women's Suffrage . . . . . By M. G. Fawcett, LL.D.
48. The Working of the British System of Government to-day . . By Prof. Ramsay Muir, M.A.
49. An Introduction to Economic Science By Prof. H. O. Meredith, M.A.
50. Socialism . . . . By F. B. Kirkman, B.A.
79. Socialist Theories in the Middle Ages By Rev. B. Jarrett, O.P., M.A.
*80. Syndicalism . . . . . . By J. H. Harley, M.A.
81. Labour and Wages . . . . . By H. M. Hallsworth, M.A., B.S
*82. Co-operation . . . . . . By Joseph Clayton.
*83. Insurance as Investment . . . By W. A. Robertson, F.F.A.
*92. The Training of the Child . . . By G. Spiller.
105. Trade Unions . . . . . . By Joseph Clayton.
*106. Everyday Law . . . . . . By J. J. Adams.

LETTERS

*51. Shakespeare . . . . . . By Prof. C. H. Herford, Litt.D.
*52. Wordsworth . . . . . . By Rosaline Masson.
*53. Pure Gold—A Choice of Lyrics and Sonnets . . . . By H. C. O'Neill.
*54. Francis Bacon . . . . . . By Prof. A. R. Skemp, M.A.
*55. The Brontës . . . . . . By Flora Masson.
*56. Carlyle . . . . By the Rev. L. MacLean Watt.
*57. Dante . . . . By A. G. Ferrers Howell.
58. Ruskin . . . . By A. Blyth Webster, M.A.
59. Common Faults in Writing English By Prof. A. R. Skemp, M.A.
*60. A Dictionary of Synonyms . . . By Austin K. Gray, B.A.
84. Classical Dictionary . . . . By A. E. Stirling.
*85. History of English Literature . . By A. Compton-Rickett.
86. Browning . . . . By Prof. A. R. Skemp, M.A.
87. Charles Lamb . . . . . . By Flora Masson.
88. Goethe . . . . By Prof. C. H. Herford, Litt.D.
89. Balzac . . . . By Frank Harris.
90. Rousseau . . . . By H. Sacher.
91. Ibsen . . . . By Hilary Hardinge.
*93. Tennyson . . . . By Aaron Watson.
107. R. L. Stevenson . . . . . By Rosaline Masson.
108. Shelley . . . . By Sydney Waterlow.
109. William Morris . . . . . By A. Blyth Webster, M.A.

LONDON AND EDINBURGH: T. C. & E. C. JACK
NEW YORK: DODGE PUBLISHING CO.